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MONTHLY NOTICES

OF THE

OYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1902 *TO NOVEMBER* 1903.

(WITH TWO APPENDICES)

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXIII. NOVEMBER 14, 1902. No. 1

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

Francis Kennedy McClean, Rusthall House, Tunbridge Wells; and
Rev. Edwin Albert Phillips, B.A., Lecturer on Mathematics, Training College, Exeter,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Henry Bourget, D. ès Sc., Maître de Conférences à l'Université de Toulouse et Astronome-adjoint à l'Observatoire de Toulouse (proposed by H. Deslandres);
Major John Cassells, V.D., J.P., 154 Queen's Drive, Crosshill, Glasgow (proposed by John Dansken);
Patrick Sinclair Hardie, M.A., B.Sc., Mathematical Master, 305 Onslow Drive, Dennistoun, Glasgow (proposed by J. McCarthy); and
Richard Kerr, F.G.S., Lecturer on Astronomy, Experimental Physics, &c., 13 Ormiston Road, Greenwich, S.E. (proposed by E. W. Maunder).

One hundred and sixty-four presents were announced as having been received since the last meeting, including amongst others:—

T. W. Backhouse, publications of West Hendon House Observatory, No. 2, presented by Mr. Backhouse; F. H. Bigelow, Eclipse Meteorology and allied problems, presented by the author; J. Bossert, Détermination des mouvements propres des étoiles, &c. [4 memoirs], presented by the author; Breslau, Universitäts-Sternwarte, Festschrift zum 90 Geburtstage des Herrn Prof. J. G. Galle, presented by the Observatory; Cape of Good Hope, Geodetic Survey, vol. 2, Report on re-discussion of Bailey's and Fourcade's surveys, &c. by Sir D. Gill, presented by the Observatory; Agnes M. Clerke, History of Astronomy during the 19th century, 4th edition, presented by A. & C. Black; B. Hasselberg, Spectra der Metalle, VI., Molybdän, presented by the author; E. W. Maunder, Astronomy without a telescope, presented by Witherby & Co.; Oxford University Observatory, Miscellaneous papers, 1899–1900, presented by the Observatory; South Kensington, Solar Physics Observatory, The Sun's spotted area, 1832–1900, presented by the Observatory; S. Tromholt, Catalog der in Norwegen beobachteten Nordlichter, presented by the Christiania Society of Sciences; C. A. Young, Manual of Astronomy, presented by the author; 2 photographs of Perrine's Comet, presented by the Astronomer Royal and 4 photographs presented by R. C. Johnson; portrait of John Goodricke, presented by W. T. Lynn; 3 photographs of Presidents of the Society, presented by W. H. Wesley.

Sur la Précision des Mesures Photographiques: Réponse à deux Notes de M. H. C. Plummer. Par M. Loewy.

Dans les *Monthly Notices*, vol. lxi., Supplementary Number, p. 618–628 et vol. lxii., No. 7 (1902 May), p. 506–516, M. Plummer formule des critiques nombreuses sur les conclusions auxquelles je suis parvenu dans mes mémoires relatifs à la précision des coordonnées des astres obtenues à l'aide des mesures effectuées sur leurs images photographiées.

Le dernier numéro (1902 May) ne m'étant parvenu que dans le courant du mois de Juin dernier, il m'a été impossible de présenter à la Société royale Astronomique, dans sa séance de Juin, la réponse que je dois opposer aux allégations de M. H. C. Plummer, allégations qui, je n'hésite pas à le dire, étonneront les astronomes qui ont fait des applications rationnelles de la méthode des moindres carrés.

On peut classer les critiques de M. Plummer en deux catégories: les unes reposent sur des interprétations erronées

des tableaux de nombres publiés dans mes mémoires ; les autres ont le caractère d'affirmations pures et simples, dénuées de toute démonstration, en contradiction d'ailleurs avec la réalité des faits.

Ce qui produit un antagonisme aussi absolu entre les vues de M. Plummer et les miennes, c'est que :

1°. M. Plummer ne semble pas se rendre suffisamment compte du caractère différent des erreurs qui interviennent dans toute étude de précision et qui peuvent être classées en trois catégories : erreurs purement accidentelles—erreurs possédant une permanence plus ou moins prolongée, comparables à des inégalités de courtes périodes et affectant d'une même manière des séries de mesures faites dans de petits intervalles de temps ou dans des conditions physiques susceptibles de varier d'un moment à l'autre—erreurs systématiques constantes.

2°. Il n'envisage, dans sa discussion, qu'un tout petit côté de la question ; il examine entre quelles limites la fréquence relative des erreurs concorde avec les règles bien connues du calcul des probabilités. On n'obtient ainsi qu'un critérium très incomplet dont M. Plummer fait souvent un usage non justifié. En dehors même de toute considération sur les conclusions dans une certaine mesure problématiques fournies par le calcul théorique, les règles qui en découlent ne peuvent se manifester que si les données conduisant aux résidus sont en nombre très considérable. C'est à cette condition seule qu'on peut espérer obtenir dans les résidus, relatifs aux deux premières catégories d'erreurs, une distribution en accord convenable avec les prévisions théoriques. Or, dans l'immense majorité des recherches, quelle que soit leur nature, une telle quantité de données homogènes fait défaut ; néanmoins les conclusions qui s'en dégagent restent exactes bien que le contrôle spécial en question n'y soit pas utilisable.

Sous ce rapport des difficultés se présentent même dans les cas les plus simples. En déterminant, par exemple, la valeur d'une inconnue à l'aide de pointés effectués sur un objet unique, astre ou mire terrestre, on est exposé, par suite des fluctuations de l'équation personnelle ou d'appréciations erronées plus ou moins persistantes sur la position du centre des images stellaires, à affecter une série de lectures successives (10 ou 20) d'une même faible erreur constante, inexactitude qui devient autre pour une seconde série exécutée plus tard.

C'est pour de semblables raisons que les astronomes n'ont qu'exceptionnellement recours à ce procédé de contrôle bien connu auquel il manque presque toujours la base nécessaire.

En examinant la loi de distribution des résidus, M. Plummer pourra se donner la satisfaction illusoire de mettre en doute tout ce qui a été publié à peu près jusqu'à l'heure actuelle par les astronomes les plus illustres qui, je suppose, n'ont pas ignoré les règles du calcul des probabilités.

M. Plummer a tenté d'invalider de cette manière quelques-unes des conclusions de mon second mémoire, mais il sera

démontré un peu plus loin que là, même où un matériel d'observations suffisant a permis de recourir à cette méthode de contrôle dont la rigueur n'est pas absolue, M. Plummer en a fait une application irrationnelle.

Le but que je me proposais dans les mémoires que je viens de publier était d'obtenir l'erreur probable réelle des coordonnées astronomiques tirées des clichés. On sait que jusqu'à présent la nature des opérations multiples exécutées dans la recherche des constantes astronomiques n'a jamais permis d'évaluer à priori le véritable degré d'exactitude du résultat cherché.

Je vais maintenant examiner en détail les objections de M. Plummer et commencer par ses deux critiques principales à l'appui desquelles il a fourni deux tableaux de chiffres empruntés à mes mémoires et qui ont une signification tout autre que celle qu'il leur attribue.

Il a été signalé, dans mon second mémoire, un fait particulier aux observateurs A et B, à savoir qu'il ne se manifeste aucune différence systématique sensible entre les coordonnées des images mesurées par eux, fait qui se produira souvent d'ailleurs pour des opérateurs exercés.

Les tableaux III-2 à III-7, pages 90 et suivantes (circ. n° 9), contiennent 258 ordonnées mesurées dans quatre orientations différentes par l'observateur A et par l'observateur B, et en outre les différences $y_A - y_B$ entre les nombres obtenus pour les deux observateurs. Ces coordonnées sont relatives à 43 étoiles sur lesquelles on a effectué 6 poses successives donnant ainsi 6 images pour chaque astre.

Lorsqu'on prend la moyenne de ces 258 différences $y_A - y_B$, on ne trouve aucun désaccord systématique entre les ordonnées y_A et y_B déterminés par les deux observateurs. La différence moyenne $\frac{yA - yB}{258} = -0''{\cdot}005$, $\pm 0''{\cdot}004$, est seulement de quelques millièmes de seconde d'arc et provient uniquement, ainsi qu'on le voit, d'inexactitudes accidentelles dans les mesures. C'est un fait incontestable. M. Plummer aurait pu, en cette circonstance, appliquer sa méthode de prédilection, puisque, dans ce cas, une des conditions essentielles du calcul des probabilités se trouve réalisée ; on est en effet en présence d'un matériel d'observations homogènes conduisant à un nombre assez respectable (258) d'erreurs de caractère accidentel.

Pour mieux mettre ce point en lumière, on a inscrit, dans le tableau suivant, le nombre réel des erreurs de $0''{\cdot}03$ en $0''{\cdot}03$, selon leur grandeur et le nombre calculé d'après la théorie. On constatera aisément que l'accord entre les deux séries de chiffres est aussi grand qu'il peut et doit l'être, d'après la vraie nature des choses.

On doit s'attendre en effet à trouver dans la réalité un nombre légèrement plus élevé pour les grands écarts, à cause de l'imperfection de quelques images et des difficultés de mesure qu'on

ntre quelquefois lorsqu'une image est placée près d'un trait leau.

Groupement et Nombre des Erreurs suivant leur Grandeur.

De o″·oo à	Réalité.	Diff.	Calcul.	Diff.
0·03	65	72	63	57
0·06	137	48	120	48
0·09	185	31	168	35
0·12	216	19	203	24
0·15	235	9	227	15
0·18	244	5	242	8
0·21	249	3	250	5
0·24	252	0	255	2
0·27	252	2	257	1
0·33	254	4	258	0
0·48	258		258	

eur probable d'une différence $y_A - y_B = \pm 0''{\cdot}065$.

ut astronome, j'en suis convaincu, conviendra qu'il n'y avait cune distinction à admettre entre les modes d'opération des bservateurs. Mais M. Plummer, qui semble être animé prédisposition systématique à la critique, ne veut pas se à l'évidence.

ici le procédé auquel il a recours pour jeter un doute sur ce t. Au lieu d'examiner la loi de distribution des 258 résidus ment fournis, distribution qui se trouve en harmonie satisfe avec le calcul théorique, M. Plummer forme la moyenne rdonnées des images relatives à une même étoile, de sorte amène la discussion, contrairement à la logique de la de des moindres carrés, à un nombre de données beaucoup re, à l'examen de 43 valeurs seulement, où le hasard aveugle manifester davantage.

lgré la voie indirecte ainsi suivie, le tableau de chiffres par M. Plummer, *Monthly Notices*, vol. lxii. p. 514, ne peut, ien interprété, que confirmer les résultats tirés des tableaux ux. Pour les 6 ordonnées relatives à 4 étoiles, on y conles différences $y_A - y_B$ de même sens, tandis que, pour s étoiles, ces différences sont affectées du signe contraire ; s 35 étoiles restantes les signes sont alternés.

ur un esprit non prévenu, ces deux séries de 4 coïncidences, même du fait qu'elles sont de sens contraires, n'ont rien prenant.

Plummer considère ces résultats comme anormaux et révélant une sorte d'incertitude systématique dans le d'opération des deux observateurs. Cette opinion est issible. Des écarts analogues se présentent, comme le

savent tous les astronomes expérimentés, dans les séries de mesures les plus simples effectuées même par un observateur seul, à de courts intervalles, sur les objets les mieux définis. La pratique enseigne à se défier des pointés consécutifs et concordants ; les divergences, qui se manifestent entre les séries séparées par de notables intervalles, donnent lieu au contraire d'espérer qu'on s'est affranchi des influences physiologiques ou physiques qui se modifient avec le temps. Dans le cas qui nous occupe deux pointés ont été faits par chacun des deux observateurs sur chacune des 6 images. Il est dans la nature des choses de rencontrer de temps à autre des permanences dans le signe des résidus.

En ce qui concerne la grandeur de quelques-uns des écarts qui excitent l'étonnement de M. Plummer (étoiles nos 15 et 29), il suffit d'examiner les résultats d'un cliché quelconque, même des mieux exécutés, pour reconnaître que les images de certaines étoiles sont moins bien venues et ne comportent pas des mesures aussi précises que les autres. Il a été de règle de mesurer à nouveau les coordonnées relatives aux résidus notables. Toutes les valeurs publiées correspondent donc à une réalité indiscutable.

La permanence des signes pour l'étoile n° 15 aurait dû être pour M. Plummer l'indice d'une imperfection relative dans une au moins des images de cette étoile. Dans le registre des mesures on trouve en effet les renseignements suivants :

Etoile n° 15, images allongées.

Etoile n° 29, dernière image du groupe I touche presque le trait du réseau.

Dans ma longue carrière j'ai souvent eu à confronter les résultats émanés de diverses sources et, comme M. Plummer, je me suis attaché quelquefois à noter la fréquence relative des erreurs. Mais la pratique m'a montré que la rareté des grands écarts doit être plutôt un motif de défiance, car elle n'est souvent qu'un résultat de la tendance des observateurs à supprimer les mesures que les écarts avec la moyenne leur dénoncent comme les plus défectueuses. Des écarts sept ou huit fois plus grands que l'erreur probable peuvent parfaitement se présenter dans la pratique et ne justifient pas la suppression des observations correspondantes. Il n'arrive pour ainsi dire jamais que l'état physiologique de l'observateur et la qualité des images stellaires présentent l'homogénéité que suppose l'application du calcul des erreurs.

La première et principale objection de M. Plummer est donc dénuée de toute base réelle et, ce qui était à prévoir, le tableau même présenté par lui ne fait que confirmer qu'il n'y a aucune distinction à établir entre les coordonnées émanant des deux observateurs A et B.

Pour des raisons analogues la seconde critique de M. Plummer n'est pas plus justifiée que la précédente. M. Plummer affirme qu'en combinant les coordonnées obtenues dans deux orientations différant de 180°, on élimine d'une manière à peu près complète

les erreurs systématiques et que les résultats ainsi obtenus offrent des garanties d'exactitude très suffisantes.

Il a été établi par mes recherches que, lorsqu'on mesure les coordonnées rectilignes dans une orientation quelconque de la plaque, ces coordonnées se trouvent affectées de deux catégories d'erreurs de mesure dont l'une provient des inexactitudes purement fortuites des pointés, et dont l'autre, d'une nature plus complexe, reste invariable et dépend de plusieurs causes dont les deux principales sont : l'erreur physiologique Es_1 de l'astronome qui ne place pas l'image au milieu des deux fils parallèles du micromètre et celle Es_2 qui provient d'une appréciation erronée du centre du disque qui, même pour les meilleures images, ne présente pas toujours une netteté parfaite.

La première Es_1 ne se manifeste pas ou à peine pour des observateurs habiles ; son influence s'éliminerait toutefois par la combinaison des mesures faites coup sur coup dans deux orientations différant de 180° ; la seconde Es_2 est indépendante de l'observateur et provient, comme je l'ai expliqué (circ. n° 9, p. 9), de tout un ensemble de causes physiques et optiques, du manque d'homogénéité de la couche de gélatine, de la définition imparfaite des images, du microscope employé aux mesures et de sa mise au foyer plus ou moins exacte, des conditions d'éclairage, etc. . . . Cette seconde source d'erreurs, dont M. Plummer nie l'existence, ne peut être évitée et les séries de mesures faites dans des orientations différentes de la plaque en subissent toujours plus ou moins l'influence.

Pour mettre ces conclusions en défaut, M. Plummer emploie les mêmes tableaux déjà cités et en fait un nouvel extrait qui le conduit à des conclusions contraires à celles qui se dégagent des nombres originaux quand on y applique directement les méthodes du calcul des probabilités.

Dans les tableaux de mon second mémoire on trouve, pour chaque étoile, 8 ordonnées mesurées dans 4 orientations différentes par chacun des deux observateurs. Pour mettre en lumière l'influence et la grandeur de chacune des deux erreurs systématiques Es_1 et Es_2, on a conclu les erreurs probables par deux méthodes différentes. La solution I a été obtenue en calculant pour chacune des 43 étoiles la moyenne M des 8 ordonnées respectives correspondantes :

$$M = \frac{y_0^A + y_{90}^A + y_{180}^A + y_{270}^A + y_0^B + y_{90}^B + y_{180}^B + y_{270}^B}{8},$$

puisqu'il n'y a aucune différence à faire entre le mode de mesure des 2 observateurs ; on a ensuite formé les résidus en comparant chacune des 8 ordonnées à leur moyenne M et de l'ensemble des résidus on a déduit les erreurs probables indiquées sous le titre solution I dans le tableau donné plus loin.

Pour la solution II, on a d'abord pris, pour chaque observateur A et B, les moyennes $\frac{y_0 + y_{180}}{2}$, $\frac{y_{90} + y_{270}}{2}$ et, ensuite, les

différences $\frac{y_0+y_{180}}{2}-\frac{y_{90}+y_{270}}{2}$, différences dès lors indépendantes de l'erreur physiologique Es_1. L'ensemble de ces résidus $\frac{y_0+y_{180}}{2}-\frac{y_{90}+y_{270}}{2}$ a conduit aux erreurs probables figurant sous le titre solution II dans le tableau ci-après :

	Solution I.		Solution II.	
	Groupe I.	Groupe III.	Groupe I.	Groupe III.
Première image	$Ep = \pm 0''095$	$Ep = \pm 0''097$	$Ep = \pm 0''088$	$Ep = \pm 0''084$
Deuxième image	$\pm 0''099$	$\pm 0''097$	$\pm 0''084$	$\pm 0''082$
Troisième image	$\pm 0''107$	$\pm 0''104$	$\pm 0''097$	$\pm 0''095$
Moyenne...	... $\pm 0''100$	$\pm 0''099$	$\pm 0''090$	$\pm 0''087$

Comme on le voit, les deux solutions révèlent d'un commun accord l'existence d'un erreur systématique Es, puisque leurs valeurs numériques dépassent notablement l'erreur accidentelle Ea d'une moyenne reposant sur deux pointés.

En prenant la moyenne entre les ordonnées respectives différant de 180°, on a rendu la seconde solution indépendante de l'erreur physiologique Es_1 ; elle ne renferme dès lors que l'erreur physique Es_2. La première solution, au contraire, où l'on a supposé l'indépendance absolue des résidus dans les diverses orientations, met en évidence la totalité de l'erreur systématique $Es = \sqrt{(Es_1)^2+(Es_2)^2}$.

Le peu de différence qui existe entre les nombres de la solution I et ceux de la solution II prouve que l'erreur physiologique Es_1, pour les deux observateurs considérés, ne joue qu'un rôle tout à fait secondaire.

M. Plummer, par une méthode purement inductive, tente de mettre en doute ces conclusions. Il forme la moyenne $M=\frac{y_0+y_{90}+y_{180}+y_{270}}{4}$ des 4 ordonnées pour chaque observateur et pour chaque image, et il compare chacune des 4 ordonnées individuelles à leur moyenne ; il obtient ainsi pour chaque image, dans chaque orientation, 43 résidus dont il forme la moyenne générale. C'est ainsi qu'il a établi (*Monthly Notices*, p. 513, vol. lxii.) un tableau dont nous allons examiner maintenant la véritable signification.

Pour mieux faire comprendre la discussion qui va suivre il est utile de fournir ici quelques courtes explications sur la manière dont les mesures ont été effectuées.

Les ordonnées des images ont été mesurées dans une position déterminée du cliché, d'une manière ininterrompue par le même observateur dans l'espace de quelques heures, par conséquent dans les mêmes conditions physiques d'éclairage, de mise au foyer, etc. . . . En outre, comme il s'agit d'images de même espèce, images à contours normaux, on doit s'attendre à ce que l'erreur

physique Es_2 ait pu conserver en majeure partie le même signe dans chaque position. Mais cette erreur physique Es_2 aura en général des valeurs différentes et des signes quelconques pour toute autre orientation.

Chaque série individuelle de 43 résidus se trouvant affectée d'une erreur systématique Es, il en résulte naturellement que chacune des 4 moyennes M_0, M_{90}, M_{180}, M_{270} de ces quatre séries de 43 résidus doit différer sensiblement de zéro. Lorsqu'on forme ensuite la moyenne M de ces quatre nombres moyens, $M=\frac{m_0+m_{90}+m_{180}+m_{270}}{4}$, et les différences $M-m_0$, $M-m_{90}$, $M-m_{180}$, $M-m_{270}$, on doit généralement rencontrer deux de ces différences affectées du signe + et les deux autres du signe −, puisque la somme de ces quatre valeurs doit être égale à 0 ; et, contrairement à la thèse de M. Plummer, des compensations forcées se produiront aussi bien pour les positions différant de 90° que pour celles différant de 180°. C'est cette conclusion si élémentaire qui n'a pas été aperçue par M. Plummer.

Plaçons maintenant sous les yeux du lecteur les nombres moyens du tableau de M. Plummer (p. 513 des *Monthly Notices*, vol. xlii.).

	Observateur A.				Observateur B.			
	0°.	180°.	90°.	270°.	0°.	180°.	90°.	270°.
yennes	+0″·096	−0″·108	+0″·072	−0″·059	+0″·073	−0″·042	+0″·035	−0″·066

Ou en écrivant ces nombres dans un ordre un peu différent on a aussi :

	Observateur A.				Observateur B.			
	270°.	0°.	180°.	90°.	270°.	0°.	180°.	90°.
yennes	−0″·059	+0″·096	−0″·108	+0″·072	−0″·066	+0″·073	−0″·042	+0″·035

On y constate sans difficulté que des compensations complètes se présentent pour les positions différant seulement de 90° ; pour l'observateur B en particulier les compensations sont encore plus complètes pour les positions différant de 90° (270 et 0) (180 et 270) que pour celles de 180°.

En résumé le tableau de M. Plummer, qui est purement inductif, ne peut fournir que des renseignements généraux complètement en accord d'ailleurs avec les conclusions fournies par l'application directe de la méthode des moindres carrés. Il indique que les opérations faites dans une seule orientation sont affectées d'erreurs systématiques qui se compensent en partie si on les combine avec des mesures réalisées dans une autre orientation quelconque. Mais, pour se rendre compte d'une manière précise de la provenance et de l'importance des erreurs systématiques, il fallait exécuter une analyse directe, comme je l'ai fait dans le second mémoire, en recherchant l'une après l'autre les diverses causes d'erreurs systématiques influant sur les résultats. Il a été

ainsi établi plus haut, qu'après avoir formé les différ
$\frac{y_0+y_{180}}{2} - \frac{y_{90}+y_{270}}{2}$, différences indépendantes de l'erreur pl
logique Es_1, les résidus décèlent la présence d'une erreur s
matique Es_2, pour laquelle on a adopté la valeur $\pm 0''$
supérieure à l'erreur physiologique Es_1 qui, à cause de sa faib
pouvait être considérée comme négligeable. S'il n'en avai
été ainsi, on aurait fait entrer dans les formules l
combiné des deux éléments Es_1 et Es_2. Il est loin d
pensée de prétendre que l'erreur physiologique Es_1 n'existe
pour d'autres observateurs ; elle se manifestera probable
d'une manière sensible dans un certain nombre de cas. Po
mettre en lumière et pouvoir en tenir compte, on n'aura
suivre la voie qui vient d'être indiquée, c'est-à-dire compare
nombres résultants des solutions I et II.

Il convient maintenant d'examiner les affirmations
lesquelles s'aventure M. Plummer.

Il en est une que je dois relever d'abord comme dénu
tout fondement et de plus peu courtoise pour les deux obs
teurs chargés des mesures des clichés relatifs à la planète .
M. Plummer a abusé d'une remarque faite à la page 11
circulaire n° 9 : "*En ce qui concerne le cliché P, que
incertitudes très légères se sont révélées au début des mesure
les observateurs A et B n'avaient pas la sûreté d'une pra
prolongée, mais ultérieurement pour tous les deux l'erreur pl
logique Es_1 s'est complètement évanouie.*"

Les deux observateurs dont il est question sont des obs
teurs excellents et, à l'exception de leurs deux ou trois prem
séances au début des opérations consacrées au cliché P, tout
nombreuses mesures ultérieures ont été exécutées par eux
des conditions de précision qui peuvent être difficilement
passées. Les quelques écarts qui se trouvent dans les séri
résidus n'étonneront aucun astronome expérimenté ; si ces é
y manquaient on serait en droit de soupçonner l'effet de sup
sions arbitraires.

M. Plummer déclare magistralement que les données qu
utilisées ne sont pas suffisantes pour déterminer les const
qui entrent dans mes formules. C'est encore une affirma
faite très à la légère.

La plupart de ces constantes ont été évaluées directer
C'est ainsi que l'erreur accidentelle Ea a été déduite de s
considérables de pointés, de même que l'erreur de pointés su
traits du réseau a été déterminée directement, les in
stellaires n'y intervenant pas. Il suffit pour fixer la grandeur d
constantes d'étudier un ou deux clichés ; mais ici ces ex
ences ont été multipliées. Ces deux constantes sont donc
à priori et d'une manière absolument indépendante les une
autres. Je ne crois pas qu'il existe un observatoire s'occu
de photographie astronomique de précision, où l'on n'ait
pratiqué ce genre d'expériences et où on ne connaîtrait pas

manière sûre la valeur numérique de ces constantes si faciles à apprécier.

Pour mettre en évidence l'accroissement de l'erreur probable provenant de la dégradation des disques stellaires, relative aux deux grandeurs-limites, les clichés suivants ont été utilisés :

1900, 23 Octobre, 58 étoiles, à 4 images.
1901, 13 Février, 83 „ 4 „
1900, 19 Octobre, 82 „ 3 „
1900, 25 Décembre { 1re pose : 43 étoiles à 3 images.
{ 2me „ 43 „ 3 „
{ 3me „ 43 „ 3 „

C'est un matériel d'observations bien supérieur à celui qui serait nécessaire pour l'évaluation des deux constantes dont dépend l'augmentation de l'erreur probable. Un seul cliché, réalisé dans des conditions d'exactitude moyenne, contenant quelques centaines d'étoiles jusqu'à la 12me grandeur environ et présentant deux ou trois images pour chaque astre, permettra de vérifier d'une manière complète ces conclusions si importantes au point de vue de la pratique. Au lieu de se contenter de produire des négations pures et simples, M. Plummer ferait mieux d'emprunter à quelque observatoire un ou deux clichés et d'effectuer sur les coordonnées mesurées quelques-unes des recherches dont il met en doute les résultats. En groupant, par exemple, les différences entre les ordonnées de deux images voisines d'un même astre suivant l'ordre de grandeur des images stellaires, il verrait de suite que l'erreur probable croît dans une proportion considérable à mesure qu'on se rapproche de la limite de visibilité des étoiles photographiées. Il constaterait en même temps que les mesures effectuées sur les disques les plus faibles sont aussi précises que celles qui se rapportent aux images les plus visibles. Il serait ainsi amené à se convaincre que l'accroissement de l'erreur probable, spécial aux deux dernières grandeurs-limites, est dû uniquement à la dégradation des disques qui n'apparaissent qu'imparfaitement sous l'action de faisceaux lumineux très faibles. Toutes ces conséquences lui sauteraient aux yeux immédiatement. L'expérience lui ferait de même toucher du doigt l'action qui tient à la déformation irrégulière de la gélatine, action qui déplace à la fois les traits du réseau et les images stellaires. Je considère comme une des plus importantes conclusions de mes dernières recherches d'avoir démontré que ces inexactitudes de nature purement physique, indépendantes des opérations de mesure, jouent un rôle capital dans la détermination des coordonnées rectilignes ; et que, si l'on n'a pas pris les précautions indiquées pour atténuer ces causes perturbatrices dans l'exécution des clichés, il devient inutile par suite de multiplier les mesures, aussi bien au point de vue du nombre des pointés que de celui des orientations. Les deux

photographie céleste, où on produit des centaines de clichés de même nature, il importe de connaître le véritable degré d'approximation avec lequel on peut tirer d'une de ces plaques les coordonnées des astres photographiés. Cette enquête si nécessaire est, heureusement, quoi qu'en pense M. Plummer, très facile à réaliser ; il suffit en suivant à peu près la voie indiquée d'étudier tout au plus deux ou trois clichés pour se rendre compte de l'influence numérique de chacune des diverses causes d'inexactitude mentionnées et dont l'ensemble altère les coordonnées conclues. Selon la constitution des clichés on trouvera, bien entendu, des valeurs différentes pour les erreurs probables correspondantes, mais on vérifiera toujours sans peine la réalité des sources qui les ont fait naître.

En utilisant les données fournies dans mon premier mémoire, circ. n° 8, M. Plummer a fourni, d'après son procédé, une appréciation de l'erreur probable d'une ordonnée mesurée dans deux orientations. Il trouve ainsi (*Monthly Notices*, vol. lxi. p. 627) $\pm 0''.060$. En présentant un tel résultat M. Plummer a omis de tenir compte de tout un ensemble de causes physiques dont la valeur numérique est maintenant connue. L'erreur réelle dans le cas considéré (cliché P, 3 images, 2 pointés, 2 orientations) est $\pm 0''.10$, et encore ce nombre ne s'applique qu'aux images précédant d'une grandeur la limite de visibilité. M. Plummer suit dans ce cas les mêmes erements que les astronomes qui, durant une partie notable du siècle écoulé, ont calculé des erreurs probables tellement en désaccord avec la réalité qu'ils ont failli compromettre l'application de la belle méthode des moindres carrés.

Il m'a paru nécessaire de répondre aux critiques de M. Plummer, critiques qui pouvaient influencer l'appréciation des lecteurs peu familiers avec les études spéciales dont il est question. Mais je ne continuerai plus une polémique qui me paraît désormais dépourvue de toute utilité.

On the Accuracy of Photographic Measures. Third Note: Reply to M. Loewy. By H. C. Plummer, M.A.

By the courtesy of the Secretaries I have been permitted to see the preceding paper in proof, and it may be convenient to have my reply at once.

In one thing at least I am in the heartiest agreement with M. Loewy. It would be quite unprofitable to prolong the present controversy. I shall therefore not be misunderstood if I do not discuss the specific points to which M. Loewy refers.

With the advantage of having read M. Loewy's reply, I should have been glad to take the opportunity to revise my

former notes. But after a most careful comparison of his paper, paragraph by paragraph, with what I have already published, I cannot admit that he has shown my conclusions to be faulty. I naturally hope that anyone who has the leisure to examine both M. Loewy's paper and my own with the same attention will arrive at the same opinion. In particular, as regards §§ 14 and 12 of my second note, to the consideration of which M. Loewy devotes fully one-half of his reply, I am perfectly willing that my words should stand as they were written.

Fortunately, with one exception, M. Loewy raises no question as to my facts or my figures. It is from the inferences based thereon that he dissents. The inferences must be left to speak for themselves. The one question of fact may be examined. I stated, subject to correction by M. Loewy, that the complicated formulæ and very important conclusions of his first two memoirs were based on the evidence of a single plate. He now gives a list of four plates. But the first two, if they can be identified by their dates, were devoted to the study of the influence of trails. The results of this research form the subject of two distinct papers, and really lie outside the limits of the discussion, though they receive passing mention in the second of the two memoirs in question (*Circulaire*, No. 9, p. 32). Moreover, the fourth plate is only introduced in the third memoir. Thus M. Loewy only confirms me in my belief that too much weight was attached to the evidence of the single plate P.

I am sure that it was far from M. Loewy's intention to do any injustice to my views. Yet I confess that I should have been better satisfied had he in some instances quoted my actual words. Thus I have looked in vain for the "négations pures et simples" (p. 11) to which the passage which follows can be applied. And similarly, if he had quoted the terms of my reference to the method of measuring in one orientation, the reader would have been enabled to judge for himself whether I had necessarily overlooked the other side of an important question.

In conclusion, I venture to reaffirm the limitations which I have imposed on myself throughout this discussion, and which ought not to be lost from view. Both my former notes were confined to a consideration of the accuracy of the *measures* of photographic images, and were not concerned with the accuracy of the positions of the images themselves.

University Observatory, Oxford:
1902 *November* 20.

On the Images formed by a Parabolic Mirror. Second Paper: Influence on the Measurement and Reduction of a Photograph. By H. C. Plummer, M.A.

1. The relative merits of the mirror and the objective corrected for photographic rays were keenly debated at the first conference of the Astrographic Chart Committee. The wisdom of the decision to reject the reflector for the purpose in view has not, and need not, be questioned. On the other hand, the value of the instrument for certain branches of work cannot be denied, and it is probable that the reflector will be used in the future even more extensively than at present. Already a large store of photographs has been accumulated, and it is important to ascertain how far precise results can be obtained from them. At present there seems to be little material for estimating the degree of accuracy with which reflector photographs can be measured. Though confessedly imperfect in certain directions, this note seems to show that very accurate results cannot be expected from the measurement of at least one important class of photographs of this kind.

2. In accordance with a suggestion by Professor Turner a direct comparison has been made between a photograph taken with a parabolic reflector and a plate taken at the University Observatory, Oxford, for the purpose of the Astrographic Chart Catalogue. The work gave rise to a geometrical study of the aberration of the mirror, the results of which have been given in a former paper.* A photograph of the region containing the nebula ♄V 15 *Cygni* was taken by Dr. Isaac Roberts on 1896 October 10 with an exposure of $2^h\ 18^m$, the instrument employed being his parabolic mirror of 20-inch aperture and 98-inch focal length. The region is practically coincident with that covered by a plate already taken at Oxford for the Astrographic Catalogue. In response to a request for a copy of his photograph, Dr. Roberts very kindly sent to the University Observatory a glass positive. A contact print of this copy was made on another plate, on which a réseau was also impressed. This final copy will be designated Plate A, and it is evident that, as a representation of the sky, it must be considered inferior to the original negative. Not only is the risk of distortion of the film introduced in the process of developing unréseaued plates, but the danger arising from want of perfect contact between the plates in the process of copying† has also to be borne in mind, especially when, as in this case, neither the original negative nor the intermediate positive is on plate glass. It is clear then that the material used in the discussion is drawn from a source which may be distinctly inferior to the original photograph, but the

* *Monthly Notices*, vol. lxii. p. 352.
† Cf. *Monthly Notices*, vol. lix. p. 462.

opinion may be confidently expressed that the difficulties which do present themselves in the consideration of the measures are certainly not due in any great degree to effects arising from this fact.

3. With the Plate A is to be compared the Oxford plate 1571 taken by Mr. Bellamy on 1900 August 22. It bears three exposures of 6 minutes, 3 minutes, and 1 minute respectively, and the approximate position of the plate centre is R.A. $20^h\,42^m$, Decl. $+30°$. This plate will henceforth be designated Plate B. The positions of the longest exposures had been measured by Mr. H. F. Mullis in the case of those stars, 872 in number, which showed three images. Apparently the centres of both plates are so nearly the same that the measures in the two cases may be directly connected by means of linear formulæ. Now if x_2, y_2 are the coordinates of a star on Plate A (referred to the corner of the réseau as origin) and x_2, y_2 the coordinates of the same star on Plate B, it is found by identifying four particular stars on both plates that if

$$x'_2 = -0\cdot727\ x_2 + 0\cdot010\ y_2 + 22\cdot040$$
$$x'_2 = +0\cdot010\ x_2 + 0\cdot727\ y_2 + 1\cdot420$$

then x'_2, y'_2 do not differ greatly from x_1, y_1. The transformation indicates (1) a reversal due to the fact that one photograph is taken with a reflector, the other with a refractor; (2) a change of scale due to the fact that the focal lengths of the two telescopes are in the ratio of 8 : 11 very nearly; (3) changes of orientation and of origin which are without any importance because they depend entirely on the way in which the glass positive and the réseau were placed in the making of Plate A.

4. The region common to the two plates A and B contains sixty stars which are to be found either in the Cambridge or the Leiden zones of the A.G. Catalogue. By adopting Plate B as a standard for direct comparison, we are independent of the catalogue places of these stars. Nevertheless the direct reduction of Plate A would be based on these stars, and it is therefore interesting to confine the comparison in the first instance to their coordinates. Accordingly, x'_2, y'_2 were calculated from the measures on Plate B, and x_1, y_1 were measured on Plate A. The constants of the linear formulæ

$$ax_1 + by_1 + c = x_1 - x'_2$$
$$dx_1 + ey_1 + f = y_1 - y'_2$$

were then calculated by Mr. Dyson's method,* the use of which is warranted by the number of stars. The resulting values are:

$$a = +0\cdot00134\ ; \quad d = +0\cdot00097$$
$$b = -0\cdot00049\ ; \quad e = +0\cdot00165$$
$$c = -0\cdot0350\ ; \quad f = -0\cdot0334$$

* *Monthly Notices*, vol. lv. p. 61.

of procedure is recorded. Unfortunately it is more easy to formulate a rule than to follow it, and unless an obvious point, as, for instance, the centre in the case of a disc, is chosen as the mark on which to point in measuring, it is exceedingly difficult to adhere to a consistent standard and to remain unaffected by subjective influences which vary with time and with the aspect under which an image is seen. In the present case the exposure of the reflector photograph was very long in comparison with that of the other plate, and therefore the images on it are apparently well developed—*i.e.* the fainter parts are not lost through under-exposure. The rule adopted was to set on that point of the axis of symmetry corresponding to the greatest width of the image. This point is not the focus for rays reflected at the centre of the mirror, but was chosen in the hope that it would give consistent results, and that it would not altogether fail even in the case of a star too faint to make a full impression. The drawback to this course lies in the fact that the maximum width of an image is by no means well marked, there being two ordinates of nearly equal length.* If, however, a setting is made on a point midway between these ordinates, there will be practically no distortion according to the geometrical theory, though the scale value will be that corresponding to a virtual focal length $f \sec v$, where f is the true focal length and $2v$ the angle subtended by the aperture of the mirror at the focus. Were it desired to find a scale value corresponding to the true focal length, it would be necessary to set on a point which is very near the extremity of the *complete* image in the direction of the centre of the field. But this is not possible, because this point lies outside the photographic image, the rays which should be incident on the centre of the mirror being intercepted by the plate itself.† In all this, however, it is supposed that the plate is accurately adjusted at the focus, and normal to the axis of the mirror. Now neither of these conditions is apparently fulfilled by the plate with which we have to deal. There are no point images at the centre of the plate; on the contrary, the smallest image exceeds 20″ in diameter. Nor is any marked symmetry of the field apparent about a centre which can be located with any certainty. Other causes, among which must be reckoned imperfections in the figure of the reflector, inequalities in the driving, variations of refraction, &c. conspire to produce images of a character very difficult to measure. On the whole the residuals appear more satisfactory than might have been anticipated.

6. In order to ascertain whether the plan of measurement just explained offered any advantage over bisection of the image a second series of measures was made by Mr. E. A. Gray, an observer possessing experience and skill in the measurement of astrographic plates and unbiassed by preconceived ideas as to the character of the images formed by a reflector. His measures

* See vol. lxii. p. 356.

† Vol. lxii. p. 365.

were treated in the same way as my own, and the residuals (δx) and (δy) are given in the seventh and eighth columns of the preceding table. The solution gave the following constants:

$$a = +0.00119; \quad d = +0.00086$$
$$b = -0.00066; \quad e = +0.00149$$
$$c = -0.0316; \quad f = -0.0294$$

Between this solution and that of §4 there are differences

$$+0.00015x + 0.00017y - 0.0034$$

and

$$+0.00011x + 0.00016y - 0.0040$$

These expressions represent the systematic differences between my own and Mr. Gray's measures. It is evident that they do *not* correspond to a uniform change of scale value with symmetry about a point of the plate, as should be the case according to the way in which they have been obtained. Their approach to equality indicates rather a uniform strain, as it were, perpendicular to a line whose equation is approximately

$$x + y - 23 = 0$$

or very roughly a diagonal of the plate. No reason suggests itself for this peculiarity.

7. The sums of the four series of residuals irrespective of signs place in order of increasing accuracy δx, (δy), (δx), and δy, the sums being in fact ·119, ·108, ·092, ·085 respectively. It may be inferred that both coordinates can be measured with equal precision, and it cannot be said, at present, that either method of measuring possesses any advantage over the other. The probable discordance in a single coordinate may be taken to be 0″·6. This value and the evidence that a discordance ought very rarely to exceed 2″ seem more satisfactory than might have been expected. For this reason the preceding table has been given in full. It must be remembered that these figures include not only the errors of the original reflector photograph, but also errors in the measures of the Oxford plate* and any faults possibly introduced in the double process of reproduction. On the other hand these figures apply only to a range of star-magnitude limited in both directions. Stars brighter than a certain magnitude, in this case about 7·0, cannot be measured satisfactorily. Thus the star *Leiden* 8418 (mag. 6·8) gives very bad results, while the star *Cambridge* 11715 = 52 *Cygni* (mag. 4·4) cannot be measured at all. For such stars the characteristic form of image is marred by photographic diffusion, by diffraction arising from the form of mounting of the plate carrier, and possibly in some cases by the nebulous character of the stars themselves. How far

* The mean of two measures at Oxford has been found to have a probable error of 0″·17 (*Monthly Notices*, vol. lvii. p. 628). This is independent of errors in the position of an image.

paragraph. The increased discordances are doubtless due to the fact that after the lapse of time the measures on which they depend are inconsistent with those on which was based the solution employed in the reduction.

11. The question as to how far accuracy depends on the magnitude of the stars whose positions are measured must now be considered, though the disproportion between the times of exposure of the two plates precludes a completely satisfactory answer. A selection of 45 of the faintest stars on Plate B was made, the distribution in nine groups of five stars each being similar to that employed in forming Table II. Measures were again made (1) by myself, (2) by Mr. Gray. The mean residuals are given under corresponding headings in Table IV., the first two columns of which contain the mean coordinates derived from my measures. The 'means of discordances' when compared with the corresponding figures under (1) and (3) in Table II. show that the accuracy attained is still less, as might indeed have been anticipated, than in the case of brighter stars. More especially is this the case with the x-measures obtained by the bisection method. Here again, as was noticed before, the measures seem to demand a different scale value, the mean residuals for the three distinct values of x being $+1''.53$, $-0''.33$ and $-1''.90$. The mean magnitude of the stars probably approaches 11·0. It is a little singular that the decreasing scale value with increasing faintness of the stars is a marked feature in the abscissæ but not in the ordinates. It has already been remarked (§ 9) that little weight can be attached to the residuals obtained by the method of measurement which I adopted. But in this case, if the displacements indicated by the residuals are plotted in a single diagram, they seem to suggest something of the nature of radial distortion. Here the measures might be better suited by *increased* scale values, a fact possibly due to an unconscious effort on the part of the observer to avoid the opposite effect.

TABLE IV.

		(1)		(2)	
x	y_1	δx.	δy.	δx.	δy.
		″	″	″	″
3·770	5·454	−0·6	−0·7	+1·3	+1·0
11·892	4·976	−0·3	−1·3	−0·6	+1·4
20·569	4·972	+0·2	−2·2	−1·0	+0·7
4·071	11·707	0·0	+0·2	+2·0	+0·4
11·716	11·804	−1·0	−0·8	+0·2	−1·0
20·306	11·842	+1·1	−1·2	−1·8	+0·6
4·162	19·970	−1·1	+0·2	+1·3	−1·1
11·996	19·625	−1·4	+1·3	−0·6	+0·4
20·404	19·126	−0·7	−0·2	−2·9	−0·6
Means of discordances without regard to sign:		0·93	1·08	1·57	0·90

12. This note is obviously defective in two respects. The single plate used in the discussion is a long exposure photograph. Hence any deductions which have been made cannot be applied to a reflector photograph taken with a short exposure. But since plates of the latter description are among the material available for the *Eros* parallax determination, they will shortly be exposed to the most searching practical test, and the question of the accuracy of which they are capable must soon find an answer in this way. In the second place the shortness of the exposure of the refractor photograph has made it impossible to push the comparison beyond a certain range of star magnitude which falls short of the limit of the reflector plate. In particular it is not possible to assign the degree of accuracy with which the positions of nebular condensations can be measured. That this is a question of extreme importance is shown in the case of the nebula surrounding Nova *Persei*. But it may well be that it is not susceptible of a direct answer because the mere accuracy of measurement is complicated by the difficulty of choosing a definite point to measure. An illustration is afforded by the attempt to make such measures on the Nova *Persei* nebula at the Lick Observatory.* In this case the difficulty was so great that it was met by placing an artificial mark on the under side of the plate before the photograph was placed in the measuring machine. The fact that it may be necessary to obtain the desired data by measuring such a mark shows that the mere accuracy of measurement is of secondary importance.

13. When full allowance is made for limitations such as have been alluded to in the preceding paragraph the present note still contains results which may probably be considered typical of that large and important class of photographs which have been taken with long exposures by the aid of the reflector of short focal length. Among these results the following points may be summarised :—

(1) The positions of stars with magnitudes between 7·0 and 10·0 can be measured with a probable error of about $0''{\cdot}6$ in both coordinates. As compared with astrographic plates this degree of accuracy is very low and makes it impossible to trace with certainty, from a limited amount of material, anything of the nature of genuine systematic error. On the other hand, the accuracy is of about the same order as that of the A.G. catalogues (§§ 7 and 9).

(2) Measures made on images near the edges of the plate (say 1° from the centre of the field) are certainly not more inaccurate than those made on images lying about 30′ from the centre (§§ 8–10 and Tables II. and III.).

(3) As the magnitude of stars approaches 11·0 the order of accuracy is fairly maintained, but the measures point to scale

* Lick Bulletin, No. 23.

values different from those determined from the brighter stars (§ 11 and Table IV.).

(4) Results are given in Tables I.–IV. for two distinct systems of measurement. Up to a certain point the two methods do not differ much in accuracy. The defect of the first (described in § 5) lies in the uncertainty with which measures can be reproduced after an interval or under different circumstances (§ 9 and Table II). The simple bisection method is much easier, but has the defect that it indicates a change of scale value with star magnitude, this anomaly being conspicuous in the abscissæ, but not in the ordinates (§ 11).

University Observatory, Oxford:
1902 *Nov.* 8.

William Herschel's observed Nebulous Regions, 52 in number, compared with Isaac Roberts' Photographs of the same Regions, taken simultaneously with the 20-inch reflector and the 5-inch Cooke lens. By Isaac Roberts, D.Sc., F.R.S.

William Herschel communicated a paper to the Royal Society which was published in the *Philosophical Transactions* in the year 1811, vol. 74, pp. 269 to 336, under the title of "The Construction of the Heavens"; and in a part of it is a section with the title: "Extensive Diffused Nebulosity" and "Observations of Nebulosities that have not been published before." Fifty-two regions in the sky are stated to be thus affected, and their coordinates of position and the approximate extent of the nebulosity are given in tabular form.

A century nearly has elapsed since these important statements were made, and astronomers still theorise and speculate concerning these nebulous regions in reliance upon the deservedly high eminence and conscientious care with which Herschel executed all his work. The aggregate extent of the diffused nebulosity in these fifty-two regions he estimated to cover about 151·7 square degrees, and he suggested that these represented only a small portion of the total areas in the sky that are similarly affected with nebulosity.

It occurred to me, several years ago, that it would be useful scientific work to photograph, with my 20-inch reflector, the fifty-two regions of diffused nebulosity which had been recorded by Herschel, and thus either verify, or correct, his observations in case of the absence of nebulosity. The photographs would also furnish data, that would be free from human bias and error, in the settlement of the questions, or inferences, which have been founded upon Herschel's records of these nebulous regions.

The work was commenced by me in 1896 and was completed

in 1902. The photographs have been taken, in duplicate, with the 20-inch reflector and a special lens of 5-inch aperture, made by Cooke & Sons, of York, known as Taylor's patent triplet lens. The exposures of the plate with the two instruments were made, in all cases, simultaneously and during equal times; the plates were selected and tested to be practically equal in sensitiveness; the duration of each dual exposure was ninety minutes, which my long previous experience in photographing the stars and nebulæ enabled me to judge that nebulosity of the faintness of stars of 16th to 17th magnitude would leave images upon the photographic plates exposed in the 20-inch reflector, and images of the 14th to 15th magnitude on those exposed in the 5-inch lens camera.

The results which I expected to obtain by these methods were that stars and nebulosity of at least the degree of faintness seen by Herschel would be shown on the reflector plates, and be, therefore, evidence that would be accepted with full confidence by astronomers.

The lapse of so many years since the publication of Herschel's paper, and the consequent difficulty in obtaining copies of it for study, suggested to me the desirability of quoting in my present communication to this Society, so much of it as would explain the view he then entertained concerning these nebulous regions as initial parts in "The Construction of the Heavens." The tabular method adopted by Herschel in publishing the results of his telescopic observations enables me to give the photographic results in a concise and intelligible form, coinciding line by line with his, by comparing the headings and reading the descriptive matter attached to each object respectively.

I shall now quote from Herschel's paper in the *Philosophical Transactions* above referred to.

1. "Extensive diffused Nebulosity.

2. "Observations of Nebulosities that have not been published before.

"It may be easily supposed that in my sweeps in the heavens I was not inattentive to extensive diffusions of nebulosity, which occasionally fell under my observation. They can only be seen when the air is perfectly clear, and when the observer has been in the dark long enough for the eye to recover from the impression of having been in the light.

"I have collected fifty-two such observations in a table, and have arranged them in the order of right ascension; in the first column they are numbered; in the second and third columns are the right ascension and north polar distance of a place, which is the central point of a parallelogram comprehending the space which the nebulosity was observed to fill. They are calculated for the year 1800.

"The length and breadth of the parallelograms are set down in the fourth and fifth columns in degrees and minutes of a great circle, the time taken up in the transit of each parallelo-

gram having been properly reduced to space by the polar distance given in the third column, in order to make it agree with the space contained in the breadth of the zone described by the telescope. The dimensions of the former space, therefore, is in the parallel, and that of the latter in the meridian. My field of view being fifteen minutes in diameter, its extent has been properly considered in the assigned dimensions of the parallelograms. It is, however, evident that the limits of the sweeping zone leave the extent of the nebulosity in the meridian unascertained. The beginning of it is equally uncertain, since the nebulous state of the heavens could only be noticed when its appearance became remarkable enough to attract attention. The ending is always left undetermined; for, as the right ascension was only taken once, I have allowed but a single minute of time for the extent of the nebulosity in that direction, except where the time was repeatedly taken with a view to ascertain how far it went in the parallel; or when the circumstances of its brightness pointed out a longer duration.

"The sixth column of the table contains the size of the observed nebulosity reduced to square degrees and decimals, computed from the two preceding columns; and in the last I have given the account of these nebulosities as recorded in my sweeps at the time they were made, namely, within a period of nineteen years, beginning in 1783 and ending in 1802.

"When this account says 'Affected,' it is intended to mean that the ground upon which, or through which, we see or may see stars is affected with nebulosity.

"In looking over this table it may be noticed that I have inserted several nebulosities that were only suspected. Had I been less scrupulous at the time of observation the word suspected would generally have been omitted; for with this nebulosity, as well as with the great number of nebulæ that in my catalogues are marked suspected, I have, almost without exception, found in a second review that the entertained suspicion was either fully confirmed, or that, without having had any previous notice of the former observation, the same suspicion was renewed when I came to the same place again.

"When these observations are examined with a view to improve our knowledge of the construction of the heavens, we see in the first place that extensive diffused nebulosity is exceedingly great indeed; for the account of it, as stated in the table, is 151·7 square degrees; but this, it must be remembered, gives us by no means the real limits of it, neither in the parallel nor in the meridian; moreover, the dimensions in the table give only its superficial extent; the depth or third dimension of it may be far beyond the reach of our telescopes; and when these considerations together are added to what has been said in the foregoing article, it will be evident that the abundance of nebulous matter diffused through such an expansion of the heavens must exceed all imagination.

"By nebulous matter I mean to denote that substance, or rather those substances which give out light, whatsoever may be their nature, or of whatever different powers they may be possessed.

"Another remark of equal importance arises from the consideration of the observed nebulosities. By the account of the table we find that extreme faintness is predominant in most of them; which renders it probable that our best instruments will not reach so far into the profundity of space as to see more distant diffusions of it. In No. 44 of the table we have an instance of faint milky nebulosity, which, though pretty bright in some places, was completely lost from faintness in others; and No. 46 confirms the same remark. It has also been mentioned in the first article that the nebulosity in V. 14 was brighter in three or four places than in the rest. The stars also of the Milky Way which were scattered over it, and were generally very small, appeared with a brilliancy that will admit of no comparison with the dimness of the brightest nebulosity. In consequence of this we may already surmise that the range of the visibility of the nebulous matter is confined to very moderate limits."

The photographs were taken with an exposure of the plates during 90^m in duplicate simultaneously with the 20-inch reflector and with the 5-inch Cooke lens. In all cases the objects were photographed when on or near the meridian. The reflector plates measure 2° by 2°, and the stars upon them are shown to the faintness of the 16th or 17th magnitude. On the 5 inch camera plates they are shown to the faintness of about the 14th or 15th magnitude.

Number.	R.A. 1900.	Decl. 1900.	Herschel's descriptions in the Phil. Trans. 1811.	Dates when photographs were taken.	Isaac Roberts's descriptions of his photographs.
	h m s	° ′			
1	0 10 8	9 26	Much affected with nebulosity.	1900 Nov. 22	Sky clear, stars small and faint and few in number; large areas void of stars; no nebulosity on plate.
2	0 17 37	3 59	Much affected.	1899 Sept. 5	Sky clear; stars small and faint and not very numerous; large areas void of stars; no nebulosity on plate; film dark.
3	0 22 23	29 9	Affected.	1899 Sept. 9	Sky clear; stars small and very, very numerous, one star of 5·9 mag. = D.M. 75, zone 28°, on plate; small areas void of stars; no nebulosity.
4	0 25 37	3 59	Much affected.	1900 Nov. 22	Sky clear; stars few and faint, large areas void of stars; no nebulosity on plate.
5	0 30 11	23 25	Much affected.	1900 Oct. 27	Sky clear; stars faint and numerous; nebulæ ⅉ III. 476 and N.G.C. 169, d'Arrest and Ld. R. together with other fainter ones on plate; many areas void of stars; no diffused nebulosity.

Herschel's Nos.	R.A. 1900. h m s	Decl. 1900. ° ′	Herschel's descriptions in the Phil. Trans. 1811.	Dates when photographs were taken.	Isaac Roberts's descriptio photographs.
6	0 36 28	0 29	Appeared to be affected with very faint nebulosity.	1899 Oct. 28	Sky very clear; stars s very few in number; la void of stars; son nebulæ on plate; no nebulosity.
7	0 38 0	41 10	Affected with nebulosity.	1895 Oct. 17	Sky very clear; stars cr plate; many small a of stars; several ph have been taken of th which includes the g dromeda nebula M 31 the *n.f.* end of whic cross Herschel's field o this sweep.
8	0 39 27	39 16	Unequally affected.	1900 Oct. 17	Sky clear; stars cro plate; many small a of stars; part of *s.* M 31 on plate; no othe nebulosity.
9	0 41 19	43 30	Suspected faint nebulosity.	1900 Oct. 26	Sky clear; stars su crowded on plate; m areas void of stars; n nebulosity.
10	0 48 38	43 35	Suspected faint nebulosity.	1900 Oct. 26	Sky clear; stars su crowded on plate; areas void of stars N.G.C. 317 on p diffused nebulosity.
11	1 41 8	29 48	Suspected to be tinged with milky nebulosity.	1900 Nov. 27	Sky clear; stars su numerous; large area stars; no nebulosity.
12	2 27 55	19 0	Much affected with nebulosity.	1900 Dec. 13	Sky clear; stars small very numerous; large of stars; some very faint nebulæ on p diffused nebulosity.
13	4 2 14	25 11	Much affected.	1901 Feb. 13	Sky very clear; stars numerous; large area stars; no nebulosity.
14	4 23 51	35 7	Suspected pretty strong nebulosity.	1901 Feb. 13	Sky very clear; stars crowded on *s.* and *s.p.* few on the rest of t
15	4 24 51	35 8	Suspected nebulosity.		large areas void of sta H I. 217, and also a star surrounded by nebulosity, 11″·5 *n.f.* H plate; no nebulous re
16	4 26 29	−7 30	Strong milky nebulosity.	1901 Feb. 14	Sky clear; stars small few on plate; large of stars; no nebulosi

R.A. 1900.	Decl. 1900.	Herschel's descriptions in the Phil. Trans. 1811.	Dates when photographs were taken.	Isaac Roberts's descriptions of his photographs.
h m s	° ′			
1 2	20 50	Much affected.	1901 Feb. 15	Sky very clear; stars small and very numerous; small areas void of stars; no nebulosity.
1 5	20 50	Much affected.	1901 Feb. 15	Sky very clear; stars small and crowded on plate; small areas void of stars; no nebulosity.
1 17	26 45	Strong suspicion of very faint milky nebulosity.	1901 Mar. 9	Sky clear; stars small and very few; large areas void of stars; no nebulosity.
5 50	25 1	Very much affected.	1901 Mar. 12	Sky clear; stars small and very few on plate; large areas void of stars; no nebulosity.
5 20	25 1	Affected.		
5 53	−6 56	Affected with milky nebulosity.	1901 Mar. 13	Sky clear; stars not very numerous; large areas void of stars; H IV. 33 Orionis on plate; no nebulosity.
5 10	−2 43	Affected.	1901 Mar. 12	Sky clear; stars small and very few; large areas void of stars; no nebulosity.
56	−4 18	Visible and unequally bright nebulosity. I am pretty sure that this joins to the great nebula in Orion.	1902 Mar. 5	Sky very clear; stars small and not very numerous; areas void of stars; no nebulosity on plate.
34	−2 31	Diffused milky nebulosity.	1900 Jan. 25	Sky very clear; stars very numerous on *p.* half of plate, but few on the *f.* half, where there are large areas void of stars; large cloud of nebulosity *n.f.* ζ Orionis with broad division void of stars, but with some nebulosity in *s.f.* to *n.p.* direction; other divisions break up the cloud into separate masses. To the *s.* of ζ is a stream of nebulosity 54 minutes of arc in length, with an embayment free from nebulosity dividing it in halves. Another faint nebulosity extends from ζ 27 minutes of arc towards the *s*, *s.p.* and *n.p.* The star D.M. 1001, zone −1°, is in the midst of nebulosity, and it has a companion on the *s.p.* side. The star D.M. 1005, zone −1°, is involved in a large cloud of streaky nebulosity and it has a companion on *p.* side. The star D.M. 1345, zone −2°, is H IV. 24, N.G.C. 2023. It is in the midst of a large dense streaky cloud of nebulosity which has in it condensations and remarkable rifts free from nebulosity; near the *s.* end of one of these rifts is a 12th mag. star. The star D.M. 1350, zone −2°, is in the midst of a cloud of nebulosity with some faint structure in it; it has a faint companion on the *n.p.* side. The region here referred to, which covers 4 square degrees of the sky, has so many remarkable features that it is necessary, in order to make it intelligible to the reader, to present the photograph annexed along with the above description.

Herschel's Nos.	R.A. 1900. h m s	Decl. 1900. ° ′	Herschel's descriptions in the Phil. Trans. 1811.	Dates when photographs were taken.	Isaac Roberts's descriptions of photographs.
26	5 36 52	−6 57	A pretty strong suspicion of nebulosity.	1901 Mar. 22	Sky clear; stars small and f large areas void of stars; nebulosity.
27	5 43 11	+1 8	Affected with milky nebulosity.	1901 Mar. 13	Sky clear; stars very few number; large areas void stars; no nebulosity.
28	6 1 1	+3 44	Much affected.	1902 Jan. 29	Sky clear; stars crowded e and *s.p.* sides; areas v stars; no nebulosity.
29	6 0 54	−20 27	Affected.	1902 Mar. 6	Sky clear; stars small and numerous; many areas stars; no nebulosity.
30	6 40 7	41 16	Affected.	1901 Mar. 22	Sky clear; stars few in num large areas void of stars; [illegible] VIII. 71 on plate; no losity.
31	9 27 32	−18 27	Affected.	1902 Mar. 6	Sky clear; stars small and f number; large areas stars; no nebulosity.
32	9 36 43	71 13	Much affected with very faint whitish nebulosity.	1901 Apr. 12	Sky clear; stars small numerous; several large void of stars; no nebulo
33	10 11 50	−9 3	Very faint whitish nebulosity.	1901 Apr. 15	Sky clear; stars small numerous; large areas stars; no nebulosity.
34	10 22 25	51 32	Much affected.	1901 Apr. 13	Sky clear; stars small and numerous; large areas stars; no nebulosity.
35	10 40 59	62 45	Affected with very faint nebulosity.	1901 Apr. 14	Sky clear; stars small and very numerous; large areas of stars; no nebulosity.
36	11 4 30	62 44	Affected.	1901 Apr. 15	Sky clear; stars small numerous; areas void of st several small faint nebu plate; no diffused nebulos
37	12 2 5	30 37	Affected with whitish nebulosity.	1901 Apr. 17	Sky clear; stars small and f number; large areas void stars; [illegible] II. 321 and [illegible] II. on plate; no nebulosity.
38	12 12 40	30 37	Affected with whitish nebulosity.	1901 Apr. 18	Sky clear; stars few in numb large areas void of stars; small prominent nebulæ plate; no diffused nebulosity
39	13 12 15	34 8	Much affected.	1901 Apr. 17	Sky clear; stars not v numerous; large areas void stars; no nebulosity.

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PHOTOGRAPH OF NEBULOSITY ROUND ζ ORIONIS

BY ISAAC ROBERTS, D.Sc., F.R.S.

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OGRAPH OF NEBULOSITY HERSCHEL V. 37 CYGNI

BY ISAAC ROBERTS, D.Sc., F.R.S.

R.A. 1900.	Decl. 1900.	Herschel's descriptions in the Phil. Trans. 1811.	Dates when photographs were taken.	Isaac Roberts's descriptions of his photographs.
h m s	° ′ ″			
2 20	34 8	Very much affected, and many faint nebulæ suspected.	1899 June 2	Sky clear; stars small and not numerous; areas void of stars; no nebulosity.
) 37	18 57	Affected with very faint nebulosity	1899 June 12	Sky clear; stars small and not very numerous; areas void of stars; no nebulosity.
26	— 1 53	Much affected with whitish nebulosity.	1902 Nov. 4	Sky clear; stars very numerous; no nebulosity. Herschel's sweep 42, as given in the *Phil. Trans.* (R.A. 1800 = 20^h 58^m 20^s, N.P.D. 1800 = 92° 17′) is not in sequence; as this may be due to a typographical error in one of the coordinates, a plate corresponding to (R.A. 1800 = 20^h 38^m 20^s, N.P.D. 1800 = 92° 17′) was taken on 1897 Aug. 28 as follows:
			1897 Aug. 28	Sky very clear; stars crowded on plate; no nebulosity.
15	16 44	A good deal affected.	1897 Oct. 20	Sky clear; stars crowded on plate; no nebulosity.
34	43 32	Faint milky nebulosity scattered over this space, in some places pretty bright.	1896 Oct. 10	Sky very clear; stars crowded on parts of plate; large areas void of stars on others; nebula IV.V.37, N.G.C. 7000, forms part of this region; the photograph shows it as a magnificent object. I have published a photograph of this region in Vol. II. of *Stars, Star-Clusters and Nebulæ*, Pl. 24, p. 155, and also in *Knowledge*, 1898 Nov. 1. A copy is also annexed to this paper.
' 34	— 1 34	Much affected with whitish nebulosity.	1897 Sept. 21	Sky clear; stars small and numerous; no nebulosity.
5 55	43 16	Suspected nebulosity joining to plainly visible diffused nebulosity.	1896 Oct. 10	Regions 44 and 46 are on the same plate; see description given above, No. 44.
5 8	14 21	Affected.	1899 Aug. 6	Sky clear; stars small and crowded on plate; no nebulosity.
4 15	10 19	Much affected.	1898 Oct. 12	Sky clear; stars small and numerous; areas void of stars; no nebulosity.

Herschel's Nos.	R.A. 1900. h m s	Decl. 1900. ° ′	Herschel's descriptions in the Phil. Trans. 1811.	Dates when photographs were taken.	Isaac Roberts's descriptions of photographs.
49	21 46 52	21 31	Affected.	1899 Aug. 9	Sky clear; stars small crowded; areas void of st no nebulosity.
50	22 57 24	25 45	Much affected.	1898 Sept. 20	Sky clear; stars very numer areas void of stars; no losity.
51	22 57 54	25 45	Affected.		
52	23 0 17	29 17	A little affected.	1900 Oct. 27	Sky clear; stars small and numerous; areas void of H II. 212 on plate; no nebulosity.

Conclusions.

The final results of the correlation of Herschel's fifty-two nebulous regions and my photographs can be given in a few words, as follows:

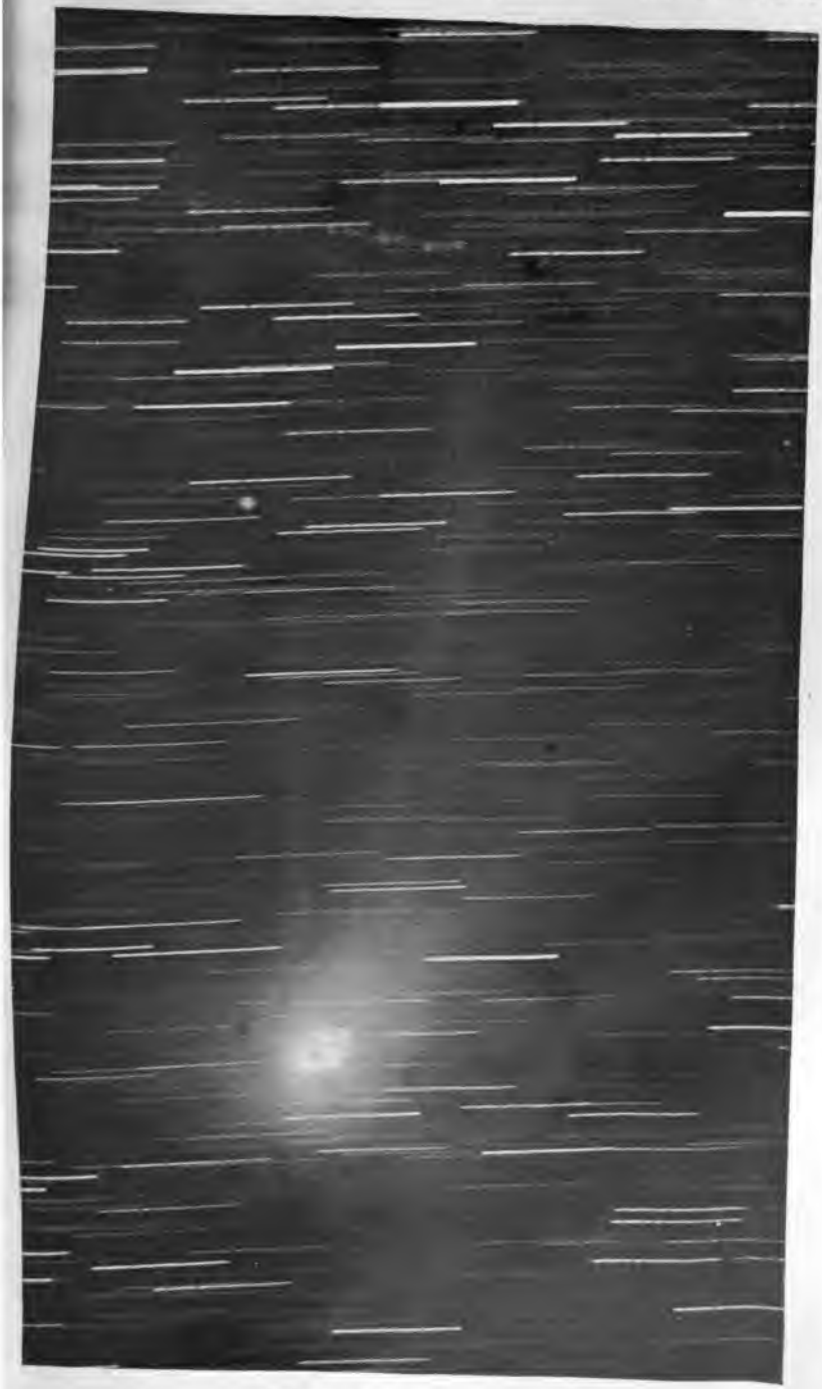
Of the fifty-two nebulous regions described by Herschel, the photographs show diffused nebulosity on four of them only; there is no visible trace of diffused nebulosity on forty-eight of the areas, but on the remaining four, which are Nos. 7, 25, 44, and 46 respectively in the table, there is nebulosity with remarkable characteristic features, and these are delineated upon three of the photographs, regions Nos. 44 and 46 being on one plate.

Two photographs have been enlarged as paper prints, and are reproduced on Plates 1 and 2, an examination of which will convey a more accurate knowledge of the objects than is possible by any descriptive matter.

Note on Photographs of Comet b 1902 (*Perrine*), *taken at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

Photographs of Comet *b* 1902 (Perrine) were obtained on twenty-seven nights, between September 6 and October 29. With the exception of one or two photographs at the beginning, the 30-inch reflector was used. Twenty-nine of the photographs of short exposure showing a well-defined nucleus have been selected for measurement for the position of the comet, and the results deduced from them will be communicated to the Society later. The exposures with the 30-inch reflector ranged from 5^m to $\frac{1}{2}^m$, according to the brightness of the comet. Besides these, seven photographs with long exposures, ranging from 13^m to 70^m, were also taken, those obtained on September 26 and September 29 (the latter reproduced on Plate 3) being of special interest. On these days the exposures were 53^m and 62^m



COMET *b* 1902, SEPT. 29

ROYAL OBSERVATORY, GREENWICH (EXP. 62 MIN.)

ctively, and "Lightning" plates were used. The telescope guided in R.A. and Dec. so as to allow for the motion of the t, and the stars are consequently shown as trails representing comet's motion during the exposure. On each of these ographs there is a bright globular head, several short tails and long faint tail extending a degree from the comet. On the ograph taken on September 29 as many as seven tails of rent lengths, divided by six narrow rifts, can be distin-ed. The direction of the long tail on both photographs is in oximately the opposite direction to the projection of the Sun he plate.

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reoscopic Pictures of Comet Perrine. By Max Wolf, Ph.D.

he two photographs presented have been made from four plates h I took with my 16-inch double photographic telescope. The 16-inch lenses are so nearly alike in size and focal length the idea occurred to me to obtain a stereoscopic effect by sing plates at slightly different times with the two lenses, at the movement of the Earth and of the comet should give ecessary shift, and I might hope to obtain the right effect by ining two plates. At first I hoped to be able to use this purpose two successive plates made with the same cope; but this gave no satisfactory results: the movement e comet was too quick.

ndeed the first of the two stereos (566 and 567) gives an st surprising view in a stereoscope. The comet hangs free ace, very near to the observer, and the trails of the fixed lie far behind. Seen with the naked eye the nebulous mass of omet on the photo is flat and opaque; in the stereoscope it like a cloud of dust, condensed towards its centre. The of the fixed stars visible through it are seen far behind, g out their own light through the tail.

he dates of these two pictures are:

566: 1902 Sept. 25, M.T. Königstuhl $7^h\ 45^m{\cdot}5$–$8^h\ 45^m{\cdot}5$

567: „ „ „ „ „ $7^h\ 55^m{\cdot}0$–$8^h\ 55^m{\cdot}0$

he second stereo:

No. 576: 1902 Oct. 1, M.T. Königstuhl $7^h\ 48^m{\cdot}1$–$8^h\ 48^m{\cdot}1$

No. 577: „ „ „ „ „ $8^h\ 3^m{\cdot}1$–$9^h\ 3^m{\cdot}1$

[ere the movement of the comet was still a little too great, at the stereoscopic effect is not as clearly visible for every ver as on the first pair: it requires to be looked at from eat distance. Still, on this picture the tail of the comet

is more interesting. The scale of the four pictures is exactly the same, and shows the increase of size and of the movement of the comet. Indeed, on a picture of October 8 the tail covers the whole plate and is longer than $3\frac{1}{2}$ degrees.

Now the stereoscope allows us to decide upon an interesting problem which occurred to me in photographing comets.

Examining the star trails on a photograph of a comet I found that every trail of a faint fixed star entering the tail of the comet, instead of becoming fainter by absorption, increases sensibly in brightness. It is a very striking appearance, and I sought for an explanation. I thought that it was produced by the increase of rapidity of the photographic film caused by the faint light of the tail, the so-called "Vorbelichtung." Now the stereo seems to show that this is wrong, and that the phenomenon is an optical effect. Viewing one print in the stereoscope with one eye—closing the other—we see the striking brightening of the star trails in the tail; opening the second eye we see this effect disappear, and the light of the dust of the comet's tail become immediately separated from the light of the fixed star, so that the star trail retains nearly exactly its own brightness while travelling behind the tail of the comet.

In making reproductions of original plates of comets I always found the sky very much brighter on the side of the tail, even many degrees from the comet's nucleus and over a very large area, so that there is no doubt that the cometic matter fills all space around.

Heidelberg, Königstuhl Astrophys. Observatory:
1902 October 22.

[The stereoscopic pictures are placed in the Library.]

Note on a Comparison of Groombridge's Catalogue (1810) *with the Greenwich Second Ten-Year Catalogue* (1890), *with reference to the Question of an Apparent Rotation of the Brighter Fixed Stars as a Whole with respect to the Fainter Stars.*

(*Communicated by the Astronomer Royal.*)

In a preliminary note in *Astronomische Nachrichten*, No. 3800, Sir David Gill concludes, as the result of a comparison of Taylor's Madras Catalogue with modern Cape Catalogues, that the brighter stars rotate with respect to the fainter stars as a whole. As in the preparation of the Greenwich Second Ten-Year Catalogue for 1890 Groombridge's Catalogue for 1810 had been brought up to 1890 for comparison, means were to hand to see whether Dr. Gill's conclusions were supported by a comparison of observations made with an interval of eighty years in the part of

from 35° to 50° N.P.D. Nearer the pole the number of too few to make a comparison of much value.

he following comparison, stars were excluded for which r motion is given in the Greenwich Ten-Year Catalogue o. This was done merely as a matter of convenience in hing numerical work, as, in view of the re-reduction of ɔridge's observations now in progress, this comparison is ɔ be regarded as a provisional one. This method of m leaves out stars of large proper motion, and also all the bserved by Bradley for which the proper motions obtained wers were adopted in the Ten-Year Catalogue, but as s cosmical distribution of the stars is quite fortuitous. the re-reduction of Groombridge's observations is finished complete and detailed comparison will be made, but it is rest to place the present comparison on record in view of vid Gill's paper.

f Right Ascension of the Greenwich Second Ten-Year Catalogue (1890) *ombridge's Catalogue* (1810) *for the Stars between* 35° *and* 50° *N.P.D.*

	Mag. 5·0–5·9.		Mag. 6·0–6·9.		Mag. 7·0–7·9.		Mag. 8·0–8·9.	
	Diff.	No. of Stars.	Diff.	No. of Stars.	Diff.	No. of Stars.	Diff.	No. of Stars
h	s		s		s		s	
3	+·29	16	+·06	50	+·09	136	+·03	89
6	+·22	16	+·13	41	+·11	94	+·01	67
9	+·23	8	−·06	43	−·06	72	−·12	38
2	·00	11	+·04	27	−·14	77	−·04	28
5	−·09	8	−·03	22	−·03	39	−·13	23
8	−·06	9	+·03	43	−·01	69	+·06	14
1	+·22	18	+·13	104	+·12	225	+·05	181
ɔ	+·18	18	+·15	75	+·18	169	+·07	131
.	+·12	104	+·06	405	+·03	881	−·01	571

is to be noted that no magnitude-corrections have been l in forming these results, and although the progressive ıtion of the means agrees in sign with the results given by ıvid Gill, it hardly affords sufficient evidence, in view of ıknown magnitude-correction, on which to base any con- ı as to a cosmical movement of the nature indicated by Gill.

will be of interest to see how far these results will be d by the re-reduction of Groombridge's observations now completed.

Newcomb's Fundamental Catalogue: Notes and Errata.

By W. G. Thackeray.

Notes.

The places and proper motions of the two following stars, the first in R.A. and Dec., the second in R.A. only, do not appear to be correct, apparently owing to the Piazzi places being discordant.

The following data, reduced to 1900 with Struve's precession and no proper motion, have not been corrected for systematic differences of the catalogues.

The Groombridge Catalogue places are from the new reductions.

No. 1464.

Catalogue.	R.A. 1900.	Epoch.	No. of Obs.	Dec. 1900.	Epoch.	N
	h. m. s.			° ′ ″		
Piazzi xxii., 36	22 9 34·44	1800	10	38 43 9·5	1800	
Groombridge, 3716	34·88	1809·9	6	6·54	1809·9	
Radcliffe, 5612	34·97	1849·7	2	7·30	1849·8	
Greenwich (1860), 1859	34·99	1859·7	4	6·79	1859·8	
Brussels, 6189	34·95	1869·1	3	7·13	1869·1	
Greenwich (1872), 2085	34·98	1872·2	5	6·76	1872·2	
„ (1880), 3718	35·03	1881·1	3	7·05	1881·4	
„ (1850), 6189	35·12	1892·3	5	7·28	1891·1	
Newcomb, 1464	35·489	1900·0		6·55	1900·0	
	P.M. + 0ˢ·0126			P.M. + 0″·021		

No. 1556.

Catalogue.	R.A. 1900·0.	Epoch.	No. of Obs.
	h. m. s.		
Piazzi xxiii., 101	23 25 23·63	1800	19
Groombridge, 4078	24·50	1809·8	12
Radcliffe, 6092	24·45	1845·1	5
Brussels, 10536	24·60	1868·1	4
Helsingfors, 14105	24·55	1871·8	2
Greenwich (1890), 6681	24·68	1893·3	10½
Newcomb, 1556	24·960	1900·0	
	P.M. + 0ˢ·0072		

Errata.

Newcomb No.

60. Secular variation in Dec. 1900 *for* −44″·18 *read* −54″·18. No. in Bradley Insert 65.

1589. Seconds of R.A. 1875 and 1900 appear to be 1ˢ too great.

Another Form of Micrometer for Measuring Star Positions.

By H. C. Russell, C.M.G., F.R.S.

When working with the beautiful Star-measurer designed by Sir David Gill, I noticed the accuracy of the work, and its convenience for the purpose; but I was struck with the time taken to move the micrometer spider lines across a réseau square, and I came to the conclusion that it would be an improvement to have a quicker motion than the screw provided, without reducing the accuracy. I have also provided that microscopes should conveniently and rapidly read the positions in minutes, seconds, and tenths of seconds of arc, and the reader writes them down with a small type-writer, so that he need not take his eye from the microscopes, and can easily read and write them down in half a minute. So much is claimed; let us see the mechanism.

Fig. I. (Plate 4).—Here the machine is in complete order for use; A is a thin board to protect the graduated circles from the observer's breath, and the thin nickel-plated circles B and C were raised to give more room over the axes of the graduated circles.

Fig. II.—The thin board removed exposes the two graduated circles 5 inches in diameter: they are graduated only $\frac{1}{4}$ of the circumference. This space is divided into 5 minutes, and each minute is subdivided into 60 seconds—that is, into the space of a réseau on the photographic plates. Each microscope has a grating in the eyepiece which divides every second into 10 parts. When at work the lower parts of the observer's hands rest comfortably on B and C′, and the fingers take H H, and turning them either way move the circles, and they are read by the microscopes F and G, and recorded by a small type-writer (not shown in the photograph), so that each observer is conveniently placed, and has comfortable positions for eyes and hands. (Of details later.)

Plate 6 shows the details of the small cast-iron chambers under the graduated circles. Starting from plan and section, J is the exact counterpart of an ordinary microscope with cross motions (except that it has no screws so far), but instead of screws at H H there are placed pieces of the balance-spring of a watch, H, by which, instead of screws, the micrometer is moved. (See X Y plan and section and elevation and section Z Z.) H is attached to C in each axis of the graduated circles by a screw I; and the milled-headed screw J E and G, resting on the other wheels D D, is for regulating the friction

on that wheel; without it the milled head is too free to feel pleasant when bisecting a star image carefully and accurately.

The adjustment of focus and of the scale—that is, the graduations on the circles—to be exactly equal to a réseau square, five millimetres, is provided for by the compound screws K K K K (*Fig. II.*), and the focal adjustment of the microscope.

The chambers shown in Plate 6 are ¼-inch thick, are made of cast-iron, and are *dust proof*, thus keeping the changes of temperature very slow, and the effect as far as possible uniform over all the measuring parts.

Little need be said of the sliding frames for placing a réseau square in its place. There is a large hole as close to the micrometer J and as near that point as possible, so that a spot of the réseau plate under and about the microscope is easily seen for placing any part under the microscopes.

Fig. III. (Plate 5) shows the arrangement of the slides for adjusting the photograph; one ∧ guide controls the straight-line motion with perfect accuracy, the other support is on friction rollers, and the wire over the pulley carries a balance weight. The motion is all that can be desired; the cross slide hangs on the upper edge of the larger slide, and works very satisfactorily.

Sydney Observatory: 1902 *July* 29.

A Standard Scale for Telescopic Observations.

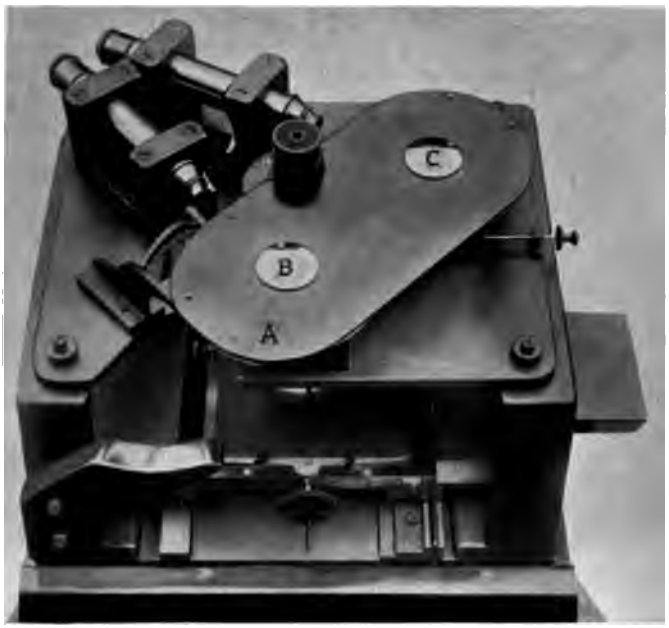
By Percival Lowell.

(*Communicated by the Secretaries.*)

1. *Present State.*—At present there exists no criterion among astronomers for the weight to be attached to any given observation due to the atmospheric conditions under which it is made. Yet these atmospheric conditions are among the most important factors entering into an astronomic observation. They are far more to the point than the size of the instrument. For our telescopes have long since outstripped the conditions under which they are put to work; the great bar to advance to-day, whether visually, photographically, or spectroscopically, being not instrument but atmosphere. Each man realises this, but marks his own work on his own scale, as if he should take his own foot as the unit of length.

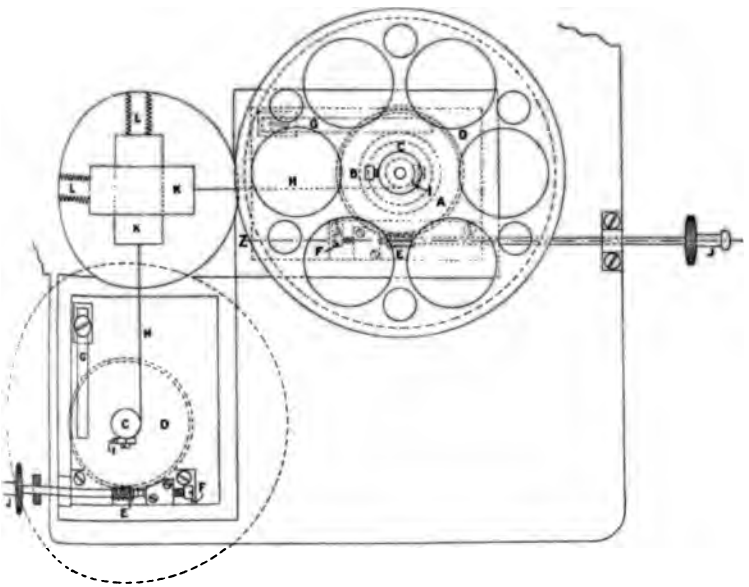
2. *Difficulties of this Condition.*—In consequence no absolute value is assignable to any man's work, and no comparison between different men's work is possible whether in accuracy or credibility. The practical outcome is that the only test is the

I.

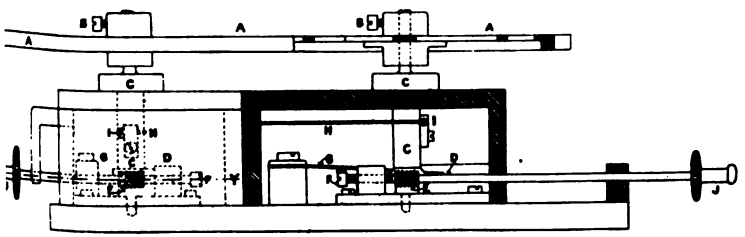


II.

PLAN AND SECTION ON XY



ELEVATION AND SECTION ON ZZ



of time, and while the world is waiting for confirmation of new result just so many years are lost.

As important is the incapacity to leave permanent records bservations capable of being compared with newer ones as rolls on.

. *A Change necessary.*—A change in this state of things is eratively needed. It is time a standard scale for observations introduced similar to what the metric system is, that it may hat that does for physics generally.

. *Possibility of a Criterion.*—Until lately such a scale has been feasible owing to ignorance of the conditions upon h it must be based. Studies, however, directed to that end at Arequipa and then at Flagstaff during the past few years resulted in the knowledge of the conditions which constitute or bad seeing, and have thus enabled an absolute scale to nstructed.

. *The Criterion.*—The basis of the matter lies in the discovery systems of waves traverse the air, several of these systems present at once at various levels above the Earth's surface. waves composing any given system are constant in size, and for the different currents all the way from a fraction of ch to several feet in length. If the wave be less than the eter of the object-glass from crest to crest the image is sed by the unequal refraction from the different phases of ave. If the wave be longer than this a bodily oscillation e whole image results. The first is fatal to good definition, econd to accurate micrometric measurement.

t is possible to see these waves by taking out the eyepiece putting one's eye in the focus of the instrument when the is pointed at some sufficiently bright light. It is further ble to measure their effect by careful noting of the character e spurious disc and rings made by a star and the extent of wing of the image in the field of view. By combining the nt of confusion with the degree of bodily motion of the ting image the definition at any time and place can be ately and absolutely recorded.

he increasing perfection of the optical image of a star testi- o the increasing lack of damaging currents with reference to bject-glass used. It records all the waves below a certain -length. Similarly the amount of bodily motion registers hose above that length. The two taken together give nt of all the currents independent of the glass.

. *The Scale.*—It is therefore necessary only to agree upon size of glass for making the fundamental tests and then to ce the results to any aperture by relations which will be found rth in a pamphlet by Mr. Douglas made at this observatory, led "Scales of Seeing."

he most feasible size for comparison purposes seems the ch aperture.

he scale it is proposed to adopt is therefore as follows :—

With a 6-inch glass—

0 Disc and rings confused and enlarged.
2 Disc and rings confused but not enlarged.
4 Disc defined ; no evidence of rings.
6 Disc defined ; rings broken but traceable.
8 Disc defined ; rings complete but moving.
10 Disc defined ; rings motionless.

Synchronous determination of the amount of bodily motion of image in seconds of arc.

Expedition for the Ascertaining of the best Location of Observatories. By Percival Lowell.

(*Communicated by the Secretaries.*)

In order to discover the best place or places for the location of telescopes in the future it is proposed to send observers furnished with similar instruments and identical instructions to all promising parts of the Earth's surface.

Two desert belts girdle the Earth in the sub-tropical regions of *Capricorn* and *Cancer*, and from the meteorologic conditions there prevailing these belts offer the greatest promise to the astronomer. In the northern hemisphere the belt shows itself first in the Sahara of Africa, then in Arabia, then in the desert of Gobi, and crossing the Pacific crops out again in Arizona and Mexico. Of these the two with the greatest height for their plateaux are Arizona and Mexico and the desert of Gobi. In the southern hemisphere we have the veldt of southern Africa, the western part of Australia, and finally the west coast of Peru and Bolivia. Of these the last is the highest and the Transvaal the next.

With regard to these places we have the most systematic series of records from Arizona, the next so from Peru, some slight knowledge of the Sahara, and next to none of any other locality.

Although the desert belts promise the best, other localities widely different should also be examined. Chief among these perhaps are the islands of the Pacific.

It is desirable, therefore, to send out observers somewhat as follows :

1. To the desert of Gobi.
2. To the veldt of the Transvaal.
3. To the Samoan Islands.

The observations made at these points could then be repeated elsewhere till the Earth's surface should be known from an astronomic point of view.

Each observer is to be armed with a 6-inch glass, all the glasses made by the same maker (for instance, Alvan Clark & Sons' Corporation), and to report according to the proposed standard scale of "seeing."

It is thus important that the said scale should be agreed to by astronomers generally before the various expeditions start.

Ephemeris for Physical Observations of the Moon for 1903.
By A. C. D. Crommelin.

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1903 Jan. 1	308°·03	+1°·48	−4°·01	−6°·04	7°·25	146°·4	342°·88
2	320·20	+1·49	−5·11	−5·37	7·42	136·4	339·52
3	332·38	+1·50	−6·08	−4·46	7·54	126·3	337·04
4	344·55	+1·50	−6·88	−3·32	7·63	115·8	335·54
5	356·72	+1·51	−7·44	−1·99	7·70	105·0	335·11
6	8·88	+1·52	−7·68	−0·53	7·70	93·9	335·89
7	21·03	+1·52	−7·53	+1·00	7·60	82·4	337·94
8	33·18	+1·53	−6·93	+2·52	7·37	70·0	341·35
9	45·31	+1·53	−5·86	+3·93	7·05	56·2	346·24
10	57·44	+1·53	−4·31	+5·12	6·69	40·1	351·90
11	69·57	+1·53	−2·38	+5·99	6·45	21·7	358·48
12	81·69	+1·54	−0·22	+6·44	6·44	2·0	5·24
13	93·81	+1·53	+1·98	+6·43	6·73	342·9	11·56
14	105·93	+1·53	+4·01	+5·97	7·19	326·1	16·92
15	118·06	+1·53	+5·70	+5·10	7·65	311·8	20·98
16	130·19	+1·52	+6·91	+3·93	7·95	299·6	23·61
17	142·32	+1·52	+7·60	+2·56	8·02	288·6	24·81
18	154·47	+1·51	+7·78	+1·09	7·86	278·0	24·64
19	166·62	+1·50	+7·49	−0·39	7·50	267·0	23·27
20	178·78	+1·50	+6·83	−1·81	7·06	255·2	20·80
21	190·94	+1·49	+5·89	−3·11	6·66	242·2	17·40
22	203·11	+1·48	+4·74	−4·25	6·37	228·1	13·23
23	215·29	+1·47	+3·47	−5·20	6·25	213·7	8·47
24	227·47	+1·46	+2·14	−5·91	6·29	199·9	3·35
25	239·65	+1·46	+0·83	−6·37	6·42	187·4	358·08
26	251·84	+1·45	−0·45	−6·55	6·56	176·1	352·93
27	264·03	+1·44	−1·65	−6·45	6·66	165·7	348·09

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat.	Geocentric Libration Combined Amount.	Geocentric Libration Direction.	
1903.	°	°	°	°	°	°	
Jan. 28	276·23	+1·43	−2·78	−6·07	6·68	155·4	34
29	288·42	+1·43	−3·82	−5·41	6·61	144·8	34
30	300·61	+1·42	−4·75	−4·49	6·54	133·4	33
31	312·79	+1·41	−5·55	−3·35	6·48	121·1	33
Feb. 1	324·98	+1·41	−6·20	−2·04	6·53	108·2	33
2	337·16	+1·40	−6·65	−0·60	6·68	95·2	33
3	349·33	+1·39	−6·86	+0·90	6·92	82·5	33
4	1·50	+1·38	−6·75	+2·40	7·16	70·4	34
5	13·66	+1·37	−6·28	+3·78	7·33	59·0	34
6	25·81	+1·36	−5·43	+4·97	7·37	47·5	34
7	37·96	+1·35	−4·17	+5·89	7·22	35·3	35
8	50·10	+1·33	−2·59	+6·44	6·94	21·9	
9	62·23	+1·32	−0·75	+6·56	6·60	6·5	
10	74·36	+1·30	+1·17	+6·23	6·34	349·4	1
11	86·49	+1·29	+3·01	+5·47	6·24	331·2	1
12	98·63	+1·27	+4·60	+4·35	6·33	313·4	2
13	110·76	+1·25	+5·81	+2·97	6·53	297·1	2
14	122·89	+1·23	+6·57	+1·45	6·73	282·4	2
15	135·04	+1·21	+6·86	−0·11	6·86	269·1	2
16	147·19	+1·19	+6·70	−1·61	6·89	256·5	2
17	159·35	+1·17	+6·15	−3·00	6·84	244·0	1
18	171·51	+1·15	+5·29	−4·21	6·76	231·5	1
19	183·68	+1·12	+4·20	−5·20	6·68	218·9	
20	195·85	+1·10	+2·97	−5·96	6·66	206·5	
21	208·03	+1·08	+1·67	−6·46	6·67	194·5	35
22	220·22	+1·06	+0·37	−6·68	6·69	183·2	35
23	232·41	+1·04	−0·87	−6·61	6·67	172·5	34
24	244·61	+1·02	−2·01	−6·26	6·58	162·2	34
25	256·81	+1·01	−3·02	−5·62	6·38	151·7	34
26	269·01	+0·99	−3·88	−4·71	6·10	140·5	33
27	281·22	+0·97	−4·58	−3·57	5·81	127·9	33
28	293·42	+0·95	−5·11	−2·23	5·58	113·6	33
Mar. 1	305·62	+0·93	−5·46	−0·76	5·51	97·9	33
2	317·82	+0·91	−5·60	+0·67	5·64	83·2	33
3	330·02	+0·90	−5·55	+2·29	6·00	67·6	33
4	342·20	+0·88	−5·25	+3·70	6·43	54·8	34
5	354·39	+0·86	−4·71	+4·93	6·82	43·7	34
6	6·56	+0·83	−3·90	+5·88	7·06	33·6	35

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat.	Combined Amount.	Direction.	C.
1903.	°	°	°	°	°	°	°
Mar. 7	18·73	+0·81	−2·85	+6·50	7·10	23·7	0·45
8	30·89	+0·79	−1·59	+6·71	6·89	13·3	6·73
9	43·05	+0·76	−0·19	+6·50	6·50	1·7	12·60
10	55·20	+0·74	+1·26	+5·86	5·99	347·9	17·60
11	67·35	+0·71	+2·65	+4·85	5·52	331·4	21·44
12	79·50	+0·68	+3·86	+3·54	5·24	312·5	23·88
13	91·64	+0·65	+4·80	+2·02	5·21	292·8	24·89
14	103·79	+0·62	+5·40	+0·42	5·42	274·4	24·48
15	115·94	+0·59	+5·63	−1·17	5·75	258·3	22·77
16	128·10	+0·56	+5·48	−2·65	6·09	244·2	19·90
17	140·26	+0·53	+5·00	−3·97	6·38	231·6	16·07
18	152·43	+0·51	+4·22	−5·06	6·59	219·8	11·53
19	164·60	+0·48	+3·21	−5·90	6·71	208·5	6·50
20	176·78	+0·45	+2·04	−6·48	6·80	197·5	1·23
21	188·97	+0·42	+0·78	−6·78	6·82	186·6	355·96
22	201·16	+0·39	−0·49	−6·78	6·80	175·9	350·92
23	213·36	+0·37	−1·69	−6·49	6·71	165·4	346·29
24	225·57	+0·34	−2·79	−5·92	6·54	154·8	342·26
25	237·78	+0·32	−3·71	−5·07	6·28	143·8	338·99
26	249·99	+0·29	−4·39	−4·02	5·96	132·5	336·62
27	262·21	+0·27	−4·91	−2·65	5·58	118·4	335·31
28	274·43	+0·25	−5·14	−1·17	5·27	102·8	335·16
29	286·65	+0·22	−5·11	+0·40	5·13	85·5	336·28
30	298·87	+0·20	−4·85	+1·98	5·24	67·8	338·68
31	311·08	+0·18	−4·36	+3·46	5·56	51·6	342·36
Apr. 1	323·30	+0·15	−3·67	+4·76	6·01	37·6	347·17
2	335·50	+0·13	−2·82	+5·79	6·44	26·0	352·86
3	347·70	+0·10	−1·85	+6·48	6·74	16·0	359·04
4	359·90	+0·07	−0·79	+6·77	6·82	6·7	5·31
5	12·08	+0·05	+0·30	+6·65	6·66	357·4	11·20
6	24·27	+0·02	+1·37	+6·12	6·27	347·4	16·33
7	36·44	−0·01	+2·38	+5·22	5·74	335·5	20·41
8	48·61	−0·04	+3·26	+4·01	5·17	320·9	23·23
9	60·78	−0·07	+3·97	+2·56	4·72	302·8	24·71
10	72·94	−0·11	+4·47	+1·00	4·58	282·6	24·81
11	85·11	−0·14	+4·72	−0·60	4·76	262·8	23·57
12	97·27	−0·17	+4·71	−2·14	5·17	245·6	21·12
13	109·44	−0·20	+4·42	−3·53	5·66	231·4	17·61

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1903.	°	°	°	°	°	°
Jan. 28	276·23	+ 1·43	− 2·78	− 6·07	6·68	155·4
29	288·42	+ 1·43	− 3·82	− 5·41	6·61	144·8
30	300·61	+ 1·42	− 4·75	− 4·49	6·54	133·4
31	312·79	+ 1·41	− 5·55	− 3·35	6·48	121·1
Feb. 1	324·98	+ 1·41	− 6·20	− 2·04	6·53	108·2
2	337·16	+ 1·40	− 6·65	− 0·60	6·68	95·2
3	349·33	+ 1·39	− 6·86	+ 0·90	6·92	82·5
4	1·50	+ 1·38	− 6·75	+ 2·40	7·16	70·4
5	13·66	+ 1·37	− 6·28	+ 3·78	7·33	59·0
6	25·81	+ 1·36	− 5·43	+ 4·97	7·37	47·5
7	37·96	+ 1·35	− 4·17	+ 5·89	7·22	35·3
8	50·10	+ 1·33	− 2·59	+ 6·44	6·94	21·9
9	62·23	+ 1·32	− 0·75	+ 6·56	6·60	6·5
10	74·36	+ 1·30	+ 1·17	+ 6·23	6·34	349·4
11	86·49	+ 1·29	+ 3·01	+ 5·47	6·24	331·2
12	98·63	+ 1·27	+ 4·60	+ 4·35	6·33	313·4
13	110·76	+ 1·25	+ 5·81	+ 2·97	6·53	297·1
14	122·89	+ 1·23	+ 6·57	+ 1·45	6·73	282·4
15	135·04	+ 1·21	+ 6·86	− 0·11	6·86	269·1
16	147·19	+ 1·19	+ 6·70	− 1·61	6·89	256·5
17	159·35	+ 1·17	+ 6·15	− 3·00	6·84	244·0
18	171·51	+ 1·15	+ 5·29	− 4·21	6·76	231·5
19	183·68	+ 1·12	+ 4·20	− 5·20	6·68	218·9
20	195·85	+ 1·10	+ 2·97	− 5·96	6·66	206·5
21	208·03	+ 1·08	+ 1·67	− 6·46	6·67	194·5
22	220·22	+ 1·06	+ 0·37	− 6·68	6·69	183·2
23	232·41	+ 1·04	− 0·87	− 6·61	6·67	172·5
24	244·61	+ 1·02	− 2·01	− 6·26	6·58	162·2
25	256·81	+ 1·01	− 3·02	− 5·62	6·38	151·7
26	269·01	+ 0·99	− 3·88	− 4·71	6·10	140·5
27	281·22	+ 0·97	− 4·58	− 3·57	5·81	127·9
28	293·42	+ 0·95	− 5·11	− 2·23	5·58	113·6
Mar. 1	305·62	+ 0·93	− 5·46	− 0·76	5·51	97·9
2	317·82	+ 0·91	− 5·60	+ 0·67	5·64	83·2
3	330·02	+ 0·90	− 5·55	+ 2·29	6·00	67·6
4	342·20	+ 0·88	− 5·25	+ 3·70	6·43	54·8
5	354·39	+ 0·86	− 4·71	+ 4·93	6·82	43·7
6	6·56	+ 0·83	− 3·90	+ 5·88	7·06	33·6

reenwich Midnight.	Selenographical Colong.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat.	Combined Amount.	Direction.	C.
1903.	°	°	°	°	°	°	°
Mar. 7	18·73	+0·81	−2·85	+6·50	7·10	23·7	0·45
8	30·89	+0·79	−1·59	+6·71	6·89	13·3	6·73
9	43·05	+0·76	−0·19	+6·50	6·50	1·7	12·60
10	55·20	+0·74	+1·26	+5·86	5·99	347·9	17·60
11	67·35	+0·71	+2·65	+4·85	5·52	331·4	21·44
12	79·50	+0·68	+3·86	+3·54	5·24	312·5	23·88
13	91·64	+0·65	+4·80	+2·02	5·21	292·8	24·89
14	103·79	+0·62	+5·40	+0·42	5·42	274·4	24·48
15	115·94	+0·59	+5·63	−1·17	5·75	258·3	22·77
16	128·10	+0·56	+5·48	−2·65	6·09	244·2	19·90
17	140·26	+0·53	+5·00	−3·97	6·38	231·6	16·07
18	152·43	+0·51	+4·22	−5·06	6·59	219·8	11·53
19	164·60	+0·48	+3·21	−5·90	6·71	208·5	6·50
20	176·78	+0·45	+2·04	−6·48	6·80	197·5	1·23
21	188·97	+0·42	+0·78	−6·78	6·82	186·6	355·96
22	201·16	+0·39	−0·49	−6·78	6·80	175·9	350·92
23	213·36	+0·37	−1·69	−6·49	6·71	165·4	346·29
24	225·57	+0·34	−2·79	−5·92	6·54	154·8	342·26
25	237·78	+0·32	−3·71	−5·07	6·28	143·8	338·99
26	249·99	+0·29	−4·39	−4·02	5·96	132·5	336·62
27	262·21	+0·27	−4·91	−2·65	5·58	118·4	335·31
28	274·43	+0·25	−5·14	−1·17	5·27	102·8	335·16
29	286·65	+0·22	−5·11	+0·40	5·13	85·5	336·28
30	298·87	+0·20	−4·85	+1·98	5·24	67·8	338·68
31	311·08	+0·18	−4·36	+3·46	5·56	51·6	342·36
Apr. 1	323·30	+0·15	−3·67	+4·76	6·01	37·6	347·17
2	335·50	+0·13	−2·82	+5·79	6·44	26·0	352·86
3	347·70	+0·10	−1·85	+6·48	6·74	16·0	359·04
4	359·90	+0·07	−0·79	+6·77	6 82	6·7	5·31
5	12·08	+0·05	+0·30	+6·65	6·66	357·4	11·20
6	24·27	+0·02	+1·37	+6·12	6·27	347·4	16·33
7	36·44	−0·01	+2·38	+5·22	5·74	335·5	20·41
8	48·61	−0·04	+3·26	+4·01	5·17	320·9	23·23
9	60·78	−0·07	+3·97	+2·56	4·72	302·8	24·71
10	72·94	−0·11	+4·47	+1·00	4·58	282·6	24·81
11	85·11	−0·14	+4·72	−0·60	4·76	262·8	23·57
12	97·27	−0·17	+4·71	−2·14	5·17	245·6	21·12
13	109·44	−0·20	+4·42	−3·53	5·66	231·4	17·61

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Geocentric Libration Combined Amount.	Geocentric Libration Direction.	
1903.	°	°	°	°	°	°	
June 29	330·03	−1·51	+6·21	+3·12	6·95	296·7	
30	342·26	−1·52	+6·92	+1·64	7·11	283·3	
July 1	354·49	−1·52	+7·19	+0·11	7·19	270·9	
2	6·70	−1·53	+7·10	−1·38	7·23	259·0	
3	18·92	−1·53	+6·70	−2·77	7·25	247·5	
4	31·13	−1·53	+6·05	−4·00	7·26	236·5	
5	43·33	−1·53	+5·21	−5·02	7·23	226·1	
6	55·53	−1·53	+4·24	−5·80	7·17	216·2	
7	67·73	−1·53	+3·15	−6·31	7·05	206·5	
8	79·92	−1·53	+1·99	−6·53	6·83	197·0	3
9	92·[illegible]	−1·53	+0·76	−6·47	6·51	186·7	3
10	104·31	−1·53	−0·51	−6·13	6·15	175·2	3
11	116·50	−1·52	−1·81	−5·53	5·82	161·9	3
12	128·70	−1·52	−3·10	−4·68	5·61	146·5	3
13	140·91	−1·51	−4·35	−3·63	5·66	129·8	3
14	153·11	−1·50	−5·50	−2·40	6·00	113·6	3
15	165·32	−1·49	−6·49	−1·05	6·57	99·2	3
16	177·54	−1·48	−7·24	+0·38	7·25	87·0	3
17	189·76	−1·48	−7·66	+1·83	7·88	76·6	3
18	201·98	−1·47	−7·67	+3·22	8·32	67·2	3
19	214·22	−1·46	−7·20	+4·48	8·48	58·1	3
20	226·46	−1·45	−6·24	+5·51	8·32	48·6	3
21	238·70	−1·44	−4·79	+6·22	7·85	37·6	3
22	250·95	−1·43	−2·94	+6·53	7·16	24·2	
23	263·21	−1·42	−0·94	+6·38	6·45	8·4	
24	275·46	−1·41	+1·32	+5·77	5·92	347·1	
25	287·71	−1·41	+3·36	+4·76	5·82	324·8	
26	299·96	−1·40	+5·09	+3·43	6·14	304·0	
27	312·20	−1·39	+6·40	+1·91	6·68	286·6	
28	324·44	−1·38	+7·24	+0·32	7·25	272·5	
29	336·67	−1·38	+7·62	−1·25	7·72	260·7	
30	348·90	−1·37	+7·58	−2·70	8·05	250·4	
31	1·12	−1·36	+7·17	−3·97	8·20	241·0	
Aug. 1	13·33	−1·35	+6·47	−5·03	8·20	232·1	
2	25·54	−1·34	+5·57	−5·83	8·06	223·7	
3	37·74	−1·33	+4·48	−6·36	7·78	215·2	
4	49·94	−1·31	+3·28	−6·61	7·38	206·4	3
5	62·14	−1·30	+2·06	−6·57	6·89	197·4	3

Greenwich Midnight.	Selenographical Colong.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1903.	°	°	°	°	°	°	°
Aug. 6	74·33	−1·28	+0·78	−6·24	6·29	187·1	348·18
7	86·52	−1·26	−0·50	−5·65	5·67	174·9	343·89
8	98·70	−1·25	−1·77	−4·81	5·13	159·8	340·33
9	110·89	−1·23	−2·99	−3·75	4·80	141·4	337·60
10	123·09	−1·21	−4·15	−2·52	4·86	121·3	335·82
11	135·28	−1·19	−5·19	−1·16	5·32	102·6	335·06
12	147·48	−1·17	−6·07	+0·27	6·08	87·5	335·39
13	159·68	−1·15	−6·73	+1·72	6·95	75·7	336·85
14	171·88	−1·13	−7·10	+3·11	7·76	66·3	339·48
15	184·09	−1·11	−7·11	+4·37	8·35	58·4	343·25
16	196·31	−1·09	−6·73	+5·43	8·65	51·1	348·12
17	208·53	−1·07	−5·91	+6·20	8·56	43·6	353·90
18	220·76	−1·05	−4·66	+6·61	8·09	35·2	0·25
19	233·00	−1·03	−3·03	+6·59	7·25	24·7	6·72
20	245·24	−1·01	−1·15	+6·13	6·24	10·6	12·80
21	257·49	−0·99	+0·84	+5·23	5·30	350·9	17·96
22	269·73	−0·97	+2·77	+3·97	4·84	325·1	21·82
23	281·98	−0·95	+4·48	+2·44	5·10	298·6	24·17
24	294·22	−0·94	+5·84	+0·79	5·89	277·7	24·96
25	306·46	−0·92	+6·77	−0·87	6·82	262·7	24·25
26	318·69	−0·90	+7·27	−2·43	7·66	251·5	22·19
27	330·92	−0·88	+7·33	−3·81	8·26	242·5	19·00
28	343·13	−0·86	+7·01	−4·96	8·59	234·7	14·89
29	355·34	−0·84	+6·36	−5·84	8·63	227·5	10·12
30	7·55	−0·82	+5·45	−6·43	8·43	220·3	4·95
31	19·75	−0·80	+4·36	−6·72	8·01	213·0	359·61
Sept. 1	31·95	−0·77	+3·14	−6·73	7·43	205·0	354·35
2	44·14	−0·75	+1·87	−6·44	6·71	196·2	349·39
3	56·33	−0·73	+0·58	−5·88	5·91	185·6	344·94
4	68·51	−0·70	−0·68	−5·06	5·11	172·3	341·16
5	80·69	−0·67	−1·88	−4·02	4·44	154·9	338·20
6	92·87	−0·64	−2·97	−2·78	4·07	133·1	336·16
7	105·04	−0·61	−3·94	−1·41	4·18	109·7	335·15
8	117·22	−0·59	−4·76	+0·05	4·76	89·4	335·22
9	129·40	−0·56	−5·40	+1·53	5·61	74·2	336·42
10	141·58	−0·53	−5·82	+2·95	6·53	63·1	338·79
11	153·77	−0·50	−5·99	+4·25	7·35	54·6	342·30
12	165·96	−0·47	−5·87	+5·35	7·95	47·6	346·87

F.

Greenwich Midnight.	Selenographical Colong.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.	C.
1903	°	°	°	°	°	°	°
Sept. 13	178·16	−0·45	−5·44	+6·18	8·24	41·4	352·32
14	190·36	−0·42	−4·70	+6·66	8·15	35·2	358·37
15	202·57	−0·39	−3·66	+6·75	7·68	28·5	4·66
16	214·78	−0·37	−2·34	+6·42	6·83	20·0	10·73
17	227·00	−0·34	−0·84	+5·67	5·73	8·4	16·10
18	239·23	−0·32	+0·77	+4·53	4·59	350·4	20·42
19	251·46	−0·29	+2·35	+3·10	3·89	322·8	23·36
20	263·69	−0·27	+3·89	+1·46	4·16	290·6	24·81
21	275·92	−0·25	+4·98	−0·24	4·99	267·2	24·73
22	288·15	−0·23	+5·86	−1·90	6·16	252·0	23·19
23	300·38	−0·20	+6·36	−3·40	7·21	241·9	20·37
24	312·60	−0·18	+6·49	−4·67	7·99	234·3	16·49
25	324·81	−0·15	+6·24	−5·67	8·44	227·7	11·82
26	337·02	−0·13	+5·66	−6·36	8·52	221·7	6·65
27	349·22	−0·10	+4·81	−6·75	8·29	215·5	1·26
28	1·42	−0·07	+3·74	−6·83	7·79	208·7	355·90
29	13·61	−0·05	+2·53	−6·61	7·08	200·9	350·81
30	25·79	−0·02	+1·24	−6·11	6·23	191·5	346·19
Oct. 1	37·97	+0·01	−0·04	−5·35	5·35	179·6	342·20
2	50·15	+0·04	−1·27	−4·36	4·54	163·8	338·99
3	62·31	+0·07	−2·39	−3·16	3·96	142·9	336·66
4	74·48	+0·10	−3·34	−1·80	3·79	118·3	335·33
5	86·64	+0·13	−4·09	−0·34	4·10	94·8	335·08
6	98·80	+0·17	−4·62	+1·17	4·77	75·8	335·98
7	110·96	+0·20	−4·90	+2·64	5·57	61·7	338·08
8	123·12	+0·23	−4·93	+4·00	6·35	50·9	341·37
9	135·29	+0·26	−4·73	+5·16	7·00	42·5	345·75
10	147·45	+0·29	−4·29	+6·05	7·41	35·3	351·06
11	159·62	+0·32	−3·65	+6·60	7·54	28·9	357·00
12	171·80	+0·34	−2·82	+6·77	7·33	22·6	3·20
13	183·98	+0·37	−1·86	+6·54	6·80	15·9	9·24
14	196·18	+0·40	−0·79	+5·91	5·96	7·6	14·70
15	208·37	+0·42	+0·35	+4·90	4·91	355·9	19·23
16	220·58	+0·44	+1·50	+3·59	3·89	337·3	22·54
17	232·78	+0·47	+2·60	+2·05	3·31	308·2	24·47
18	245·00	+0·49	+3·60	+0·39	3·62	276·2	24·94
19	257·21	+0·51	+4·43	−1·27	4·61	254·0	23·98
20	269·43	+0·53	+5·04	−2·83	5·78	240·7	21·65

Greenwich Midnight.	Selenographical Colong.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	O.
1903	°	°	°	°	°	°	°
Oct. 21	281·64	+0·56	+5·39	−4·20	6·83	232·1	18·14
22	293·85	+0·58	+5·44	−5·30	7·60	225·7	13·70
23	306·05	+0·60	+5·18	−6·11	8·01	220·3	8·61
24	318·26	+0·63	+4·62	−6·61	8·06	214·9	3·18
25	330·45	+0·65	+3·79	−6·78	7·77	209·2	357·70
26	342·64	+0·68	+2·74	−6·65	7·19	202·4	352·45
27	354·83	+0·70	+1·52	−6·23	6·41	193·7	347 63
28	7·01	+0·73	+0·23	−5·55	5·56	182·4	343·42
29	19·18	+0·75	−1·09	−4·63	4·75	166·8	339·95
30	31·35	+0·78	−2·31	−3·51	4·20	146·7	337·33
31	43·51	+0·81	−3·39	−2·21	4·05	123·1	335·66
Nov. 1	55·66	+0·83	−4·25	−0·79	4·32	100·5	335·03
2	67 81	+0·86	−4·82	+0·70	4·87	81·7	335·54
3	79·96	+0·89	−5·07	+2·18	5·52	66·7	337·26
4	92·10	+0·91	−4·99	+3·58	6·15	54·3	340·20
5	104·24	+0·94	−4·59	+4·81	6·65	43·7	344·34
6	116·38	+0·96	−3·89	+5·78	6·96	33·9	349·52
7	128·52	+0·99	−2·99	+6·42	7·08	25·0	355·47
8	140·67	+1·01	−1·94	+6·66	6·94	16·2	1·77
9	152·82	+1·03	−0·84	+6·50	6·55	7·4	7·96
10	164·99	+1·05	+0·26	+5·94	5·95	357·5	13·60
11	177·15	+1·07	+1·28	+5 01	5·17	345·7	18·32
12	189·32	+1·09	+2·21	+3·78	4·38	329·7	21·87
13	201·50	+1·11	+3·01	+2·34	3·81	307·9	24·11
14	213·68	+1·12	+3·68	+0·76	3·76	281·7	24·96
15	225·88	+1·14	+4·21	−0·84	4·29	258·7	24·43
16	238·07	+1·15	+4·60	−2·38	5·18	242·6	22·56
17	250·27	+1·17	+4·82	−3·76	6·12	232·0	19·49
18	262·47	+1·18	+4·86	−4·92	6·91	224 6	15·39
19	274·67	+1·20	+4·69	−5 80	7·46	219 0	10·51
20	286·87	+1·21	+4·28	−6·37	7·67	213·9	5·14
21	299·06	+1·23	+3·63	−6·62	7·55	208·7	359·62
22	311·25	+1·24	+2·75	−6·57	7·12	202·7	354·20
23	323·44	+1·26	+1·67	−6·22	6·44	195·0	349·17
24	335·62	+1·28	+0·43	−5·60	5·62	184·4	344·72
25	347·80	+1·29	−0·91	−4·75	4·84	169·2	341·00
26	359 97	+1·31	−2·25	−3·69	4·33	148·5	338·11
27	12 12	+1·32	−3·54	−2·47	4·32	124·9	336·12

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.	
1903.	°	°	°	°	°	°	
Nov. 28	24·28	+1·34	−4·65	−1·12	4·78	103·5	3
29	36·43	+1·36	−5·51	+0·30	5·52	86·9	3
30	48·58	+1·37	−6·02	+1·75	6·27	73·8	3
Dec. 1	60·71	+1·39	−6·04	+3·15	6·81	62·5	3
2	72·85	+1·40	−5·80	+4·41	7·28	52·8	3
3	84·98	+1·42	−5·05	+5·45	7·43	42·8	3
4	97·10	+1·43	−3·92	+6·17	7·31	32·4	3
5	109·23	+1·44	−2·53	+6·52	6·99	21·2	3
6	121·36	+1·45	−1·00	+6·43	6·51	8·8	
7	133·49	+1·46	+0·55	+5·92	5·95	354·7	
8	145·63	+1·47	+1·96	+5·03	5·40	338·7	
9	157·77	+1·47	+3·17	+3·83	4·97	320·4	
10	169·92	+1·48	+4·12	+2·41	4·77	300·3	
11	182·08	+1·48	+4·80	+0·86	4·88	280·2	
12	194·25	+1·48	+5·23	−0·70	5·28	262·4	
13	206·42	+1·49	+5·45	−2·20	5·88	248·0	
14	218·60	+1·49	+5·46	−3·56	6·52	236·9	
15	230·78	+1·49	+5·31	−4·71	7·10	228·4	
16	242·97	+1·49	+4·99	−5·61	7·50	221·6	
17	255·16	+1·50	+4·51	−6·21	7·68	216·0	
18	267·35	+1·50	+3·86	−6·51	7·57	210·7	
19	279·54	+1·50	+3·03	−6·49	7·16	205·0	3
20	291·73	+1·50	+2·03	−6·18	6·51	198·2	3
21	303·92	+1·51	+0·86	−5·60	5·66	188·7	3
22	316·10	+1·51	−0·44	−4·78	4·80	174·7	3
23	328·28	+1·51	−1·82	−3·76	4·18	154·2	3
24	340·45	+1·52	−3·22	−2·58	4·13	128·7	3
25	352·61	+1·52	−4·55	−1·28	4·73	105·7	3
26	4·77	+1·52	−5·72	+0·10	5·72	89·0	3
27	16·92	+1·52	−6·64	+1·50	6·81	77·3	3
28	29·07	+1·52	−7·21	+2·86	7·75	68·4	3
29	41·22	+1·52	−7·35	+4·12	8·43	60·7	3
30	53·35	+1·52	−6·99	+5·20	8·71	53·4	3
31	65·48	+1·52	−6·12	+6·00	8·57	45·6	3

The longitudes are reckoned in the plane of the M equator, the axis of reference being the radius which p through the mean centre of the visible disc. This axis there rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is taken as 1°·523, the value used in the *Connaissance des Temps*, that given by the *Nautical Almanac* being 1°·536.

The physical librations in longitude and latitude, as given by Professor Franz's formulæ, have been applied; their values are taken from the *Berliner Jahrbuch* for the days given there, and interpolated by a graphical method for the other days. But the signs in the *Jahrbuch* require to be reversed in order to reduce to the system used here.

The colongitude of the Sun is 90° (or 450°) *minus* his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270°, 0°, 90°, 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position-angle of the apparent centre from the mean centre, or, which is the same thing, the position-angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

C denotes the geocentric position-angle of the northern extremity of the Moon's axis measured eastward from the northernmost point of the disc. It has been computed by the second formula given in the Preface to the *Nautical Almanac*, but the co-ordinates of the Moon's equator have been taken from the *Connaissance des Temps*, so as to make this column consistent with the rest of the ephemeris.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

I give the method for finding the altitude of the Sun at a given point on the Moon whose position is defined: (1) by selenographical longitude and latitude; (2) by direction cosines.

In either case the Sun's selenographical colongitude and latitude (K, L supposed) must be found by interpolation from the ephemeris for the given time.

In the first case let the given point be in the position longitude M, latitude N. Longitudes are reckoned from the meridian passing through the mean centre of the disc, and the positive direction is that towards Mare Crisium. North latitudes are considered positive.

Then

$$\text{sine Sun's altitude} = \sin L \sin N + \cos L \cos N \sin (K + M).$$

In the second case let ξ, η, ζ be the direction cosines of th given point. The axes are (1) that diameter of the Moon equator which is 90° from the mean centre of the disc; (2) th Moon's polar axis; (3) the diameter through the mean centre the disc. The positive directions are as above. Mr. Saund has issued some maps of portions of the Moon's surface fro which the co-ordinates ξ, η, ζ can be taken at sight.

Then the Sun's direction cosines are:

$$\cos K \cos L, \sin L, \sin K \cos L,$$

and sine Sun's altitude

$$= \xi \cos K \cos L + \eta \sin L + \zeta \sin K \cos L.$$

Neither formula is convenient when the Sun's altitude is ve great, for an angle near 90° cannot be accurately determin from its sine. However, when the Sun is high the shadows a so inconspicuous that it is not necessary to compute his altitu with great accuracy.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.:*
1902 *September* 1.

Erratum in Mr. Aldis's paper, vol. lxii. p. 636, line 5:

for $a \times \cdot 20878$ *read* $a \times \cdot 41745$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXIII. DECEMBER 12, 1902. NO. 2

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

George McKenzie Knight, 25 Holford Square, Percy Circus, W.C.,

was balloted for and duly elected a Fellow of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Thomas Ayres, M.Sc. (Vict.), Student of Astronomy in Strassburg University, 7 Finkermattstrasse, Strassburg, Elsass, Germany (proposed by R. Wilding) ;

Charles William Keighley, Marine Engineer, Cluny Villa, Burlington Lane, Chiswick (proposed by William Schooling) ; and

Henry Norris Russell, Research Student, Cambridge University ; Oyster Bay, N.Y., U.S.A. (proposed by Sir R. S. Ball).

Sixty-six presents were announced as having been received since the last meeting, including amongst others :—

Loewy et Puiseux, Atlas Photographique de la Lune, 6me fascicule (texte et atlas) ; and 22 charts of the Photographic Chart of the Heavens, presented by the French Minister of Public Instruction ; Prof. K. D. Naegamvala, Report of the total Solar Eclipse of January 21–22, 1898, presented by the Poona Observatory ; two stereoscopic pictures of Perrine's Comet, presented by Prof. Max Wolf.

On the Suggestion made by Sir David Gill that the Brighter Fixed Stars are as a whole rotating with respect to Fainter Stars as a whole. *By* H. H. Turner, *D.Sc., F.R.S., Savilian Professor.*

1. In No. 3800 of the *Astronomische Nachrichten* there is a "Preliminary Note on an Apparent Rotation of the Brighter Fixed Stars as a whole with respect to Fainter Stars as a whole," by Sir David Gill. He found on comparing the Cape Catalogues for 1880 and 1900 that the "apparent systematic corrections . . . could not be reconciled by any of the usual hypotheses, such as parallactic motion due to translation of the Sun in space, or systematic error in R.A. depending upon magnitude." He found similar difficulties on proceeding to compare these catalogues with Taylor's Madras (1835) Catalogue, as re-reduced by Downing, and by comparisons with the Cordoba General Catalogue and Gould's Zones; and considers that we are "driven to the conclusion that the brighter stars rotate, with respect to the fainter stars as a whole, about some centre, or that Newcomb's proper motions and precession do not give star-places which would approximately represent fundamental determinations of the first point of *Aries*, as defined with respect to a much larger number of stars. Even this latter hypothesis would not account for all the facts observed."

2. Such important conclusions are deserving of the earliest possible scrutiny by any independent method likely to throw any light upon them; and as we have at Oxford material for such a scrutiny, in the shape of measures of photographs extending over nearly ten years, no time was lost in examining these measures for the phenomenon suggested by Sir David Gill. I gratefully acknowledge the help of Mr. F. C. H. Carpenter, of the Durham Observatory, in the preliminary part of this work, on which he spent many hours during a holiday visit to Oxford.

3. The question to be decided, having regard to the material available, is briefly this: Does the "magnitude-equation" of the Cambridge meridian observations, as deduced from our photographic measures, remain constant, whatever be the date when the plates are taken, or does it change with the date?* A determination of this magnitude equation from photographs taken during the years 1892–9 was given in *Monthly Notices*, vol. lx. p. 3, the

* It is, of course, a distinct disadvantage to have to bring in the Cambridge magnitude equation at all. A much more direct method of attacking the problem would be to take plates of the same regions at different epochs and compare the positions of the stars upon them. But at Oxford we have had to be content, so far, with photographing each region once only; and the Cambridge observations must be used as a connecting link.

mption being made that the proper motions of stars of any
n magnitude are in the mean zero; and that the difference
poch between the Cambridge meridian observations (about
·0) and that of the plates (about 1896·0) had therefore no
t on the result. It is just this assumption which we are
to test. Given a sufficient lapse of time, there is no difficulty
sting it thoroughly, but it was somewhat doubtful whether
ficient interval was covered by the plates taken at Oxford.
run from 1892 to the present time, about ten years; but
considerable number of both early and late plates are required
ake the comparison effective, and as the plates must also be
ibuted with some approach to uniformity round the 24^h of
, the maximum interval is reduced in practice to four or
ears.

. As a preliminary experiment the residuals Oxford—
bridge in R.A. (or rather in x-coordinate) were formed for
hotographs taken earlier than 1894·0. These were com-
d with those found in the paper of 1899 November, which
red to a later epoch on the average; and it was found that
deduced magnitude-equation was more pronounced for the
er results—i.e. *the R.A.'s of bright stars* (*mags.* 5·0 *to* 8·0) *are
asing relatively to those of faint stars* (*mags.* 8·0 *to* 9·5) *in
elt* +25° *to* +30° *Decl.*

This conclusion, which was scarcely more than suggested by
preliminary work, was confirmed by a more extended
iry; and it does not seem necessary to give the earlier
, which needs several qualifications. But the conclusion is
d at once to draw attention to the unexpected result that
notion of the bright stars is in the *opposite direction* to that
d by Sir David Gill. In his belt of the heavens (−40° to
°) the R.A.'s of the bright stars are *increasing*; and we may
remark here the amount of the increase, which is

$$+0^s\cdot0015 \text{ per magnitude per year}$$

und by a comparison of Cape (1880·0) and Cape (1900·0);

$$+0^s\cdot0013 \text{ per magnitude per year}$$

und by a comparison of Taylor (1835·0) and Cape (1900·0).
t will be seen in what follows that the quantities found at
rd are very like these in amount, but of the contrary sign.

. The preliminary inquiries having shown that a more
led investigation might be profitably undertaken, the dates
posure of all the plates which had been measured were
ined, and it was found that in three zones of plates, +26°,
°, and +29°, groups could be formed in each octant of
of both "early" and "late" plates, the interval being
thing like five years on the average. The mean dates of the
s are given in Table I., subtracting 1890·0 in each case.

TABLE I.

Mean Date (subtracting 1890·0) and No. of Plates in each Group.

	Zone +26°.					Zone +27°.					Zone +29°.			
	Early.		Late.			Early.		Late.			Early.		Late.	
	Mean Date.	No. Plates.	Mean Date.	No. Plates.	Interval.	Mean Date.	No. Plates.	Mean Date.	No. Plates.	Interval.	Mean Date.	No. Plates.	Mean Date.	No. Plates.
h h					y					y				
0·0– 3·0	3·6	4	8·0	5	4·4	(4·7)*	0	9·4	2	(4·7)*	5·9	8	11·8	9
3·0– 6·0	3·6	5	9·6	8	6·0	5·0	13	9·1	9	4·1	6·1	5	11·4	10
6·0– 9·0	3·2	5	9·5	9	6·3	5·1	15	9·3	7	4·2	6·0	9	11·2	8
9·0–12·0	3·2	5	9·2	9	6·0	5·1	1	9·6	16	4·5	6·1	7	11·6	13
12·0–15·0	3·6	7	10·1	11	6·5	5·3	4	9·6	10	4·3	6·3	18	11·4	2
15·0–18·0	5·4	2	9·6	12	4·2	5·4	5	9·6	15	4·2	5·9	12	11·5	8
18·0–21·0	3·3	12	7·7	12	4·4	3·5	6	7·8	6	4·3	5·2	15	10·3	5
21·0–24·0	3·6	12	7·8	1	4·2	4·4	8	8·2	9	3·8	5·0	18	9·3	2
Sum or Mean		52		67	5·2		52		74	4·3		92		57

* The mean date for zones + 26° and + 29° has been substituted.

It will be seen that some of the groups contain only a small number of plates, which is natural, seeing that the work was arranged without any reference to the present purpose. But it will be presently shown that all three zones may be combined and then this weakness disappears.

6. The measures of these plates were utilised in the following way : from the Cambridge Catalogue (series of the *Astr. Gesellsch* + 25° to + 30°, epoch 1875·0) the R.A.'s and declinations have been brought up to 1900·0 and converted into standard coordinates these are used to determine the plate constants, *i.e.* the coefficients in linear expressions

$$\xi - x = ax + by + c$$
$$\eta - y = dx + ey + f$$

and using these plate constants to correct the measures, residuals are formed (Oxford—Cambridge) for the individual stars. All this is the ordinary course of the work for the Astrographic Catalogue. For the present purpose these residuals were collected into the following groups, according to the star magnitude as given in the Cambridge Catalogue.

TABLE II.

Limits of Magnitude.	Mean Mag.	Total No. Stars. +26°. E.	+26°. L.	+27°. E.	+27°. L.	+29°. E.	+29°. L.
5·0 to 6·9	6·0	60	62	62	80	89	4
7·0 „ 7·9	7·5	151	201	167	189	274	14
8·0 „ 8·8	8·5	546	649	544	651	951	48
8·9 „ 9·1	9·0	543	682	615	678	1126	56
9·2 „ 9·5	9·4	683	801	599	793	1335	53

The "mean mag." for the group was adopted as a standard for reference, and if the mean magnitude for any group came out (say) 6·25, a correction was applied to reduce the result to 6·0, using for the small interval 0·25 our general knowledge of the Cambridge magnitude equation in a manner which needs no explanation. No stars of magnitude brighter than 5·0 were included, for reasons which will be tolerably obvious on inspection of the diagram given in *Monthly Notices*, lx. p. 5.

The totals shown in Table II. will give a general idea of the amount of material available.

7. We may now set down the means of these groups, which form the raw material on which the present discussion is based. The unit of the following tables is 0·0001 of a réseau interval, or 0″·03, or 0ˢ·00222 at 26°, 0ˢ·00224 at 27°, and 0ˢ·00229 at 29°; we may take 0ˢ·00225 as the mean value in R.A. The letters E and L are used to indicate the "early" and "late" plates of Table I.

TABLE III.

Mean x Residual (Oxford – Cambridge) for each group in units of 0″·03 *or* 0ˢ·00225.

Zone +26°.

	Mag. 6·0		Mag. 7·5.		Mag. 8·5.		Mag. 9·0.		Mag. 9·4.	
	E.	L.	E.	L.	E.	L.	E.	L.	E.	L.
3	+56	+ 4	+85	+34	+18	+21	− 4	−12	−36	−28
6	+37	+46	− 2	+23	+ 5	+24	− 2	− 2	−24	−41
9	+64	+46	+38	+46	+18	+17	− 2	+ 2	−41	−28
12	+29	+43	+34	+19	+18	+10	− 8	− 3	−29	−25
15	+34	+36	+35	+32	+16	+16	+ 8	− 9	−43	−40
18	+90	+71	+44	+37	+14	+14	−10	+ 2	−26	−31
21	+44	+56	+34	+31	+24	+16	+ 3	+ 5	−28	−28
24	+61	−36	+41	+17	+21	+28	+ 7	+ 7	−32	−17
m	+51·9	+33·3	+38·6	+29·9	+16·8	+18·3	− 1·0	− 1·3	−32·4	−29·8

Zone +27°.

	Mag. 6·0		Mag. 7·5.		Mag. 8·5.		Mag. 9·0.		Mag. 9·4.	
	E.	L.	E.	L.	E.	L.	E.	L.	E.	L.
3	(+70)	+89	(+71)	+72	(+24)	+ 8	(−3)	− 9	(−33)	−38
6	+35	+35	+23	+34	+14	+29	−5	− 3	−35	−43
9	+39	+27	+40	+15	+15	+21	−4	+ 2	−34	−24
12	+94	+39	(+26)	+30	+33	+19	−3	−12	−39	−24
15	+44	+32	+41	+17	+13	+13	−8	− 4	−54	−32
18	+49	+49	+46	+25	+ 6	+11	− 2	+ 4	−25	−35
21	−48	+32	+40	+33	+19	+16	− 1	+ 3	−26	−27
24	+37	+58	+35	+39	+21	+29	+2	+ 2	−27	−30
m	+52·0	+45·1	+40·3	+33·1	+18·1	+18·3	−3·0	− 2·1	−34·1	−31·6

Zone +29°.

Octant of R.A. h h	Mag. 6·0. R.	L.	Mag. 7·5. R.	L.	Mag. 8·5. R.	L.	Mag. 9·0. R.	L.	Mag. R.
0– 3	+84	+53	+57	+32	+30	+13	− 2	−20	−29
3– 6	+38	+43	+29	+11	+ 6	+ 9	−10	− 5	−38
6– 9	+36	+72	+37	+15	+12	+19	0	+ 2	−32
9–12	+46	+16	+18	+41	+15	+14	−12	− 2	−18
12–15	+36	+ 5	+35	+35	+17	+14	− 5	− 7	−39
15–18	+35	+26	+15	+24	+12	+14	− 4	+ 2	−23
18–21	+49	+18	+35	+34	+21	+13	0	+ 3	−24
21–24	+65	+35	+41	+37	+28	+17	+ 3	−12	−29
Mean	+48·6	+33·5	+33·4	+28·6	+17·6	+14·1	− 3·8	− 4·9	−29·0

8. Now in studying such phenomena as have been suggested by Sir D. Gill he insists that "we must give equal weight to groups of stars which are symmetrically distributed in right ascension." To take the simple means of the eight octants in Table III. and compare them does not fulfil this condition; for the intervals (as may be seen by referring to Table I.) are not the same in the different octants, and an octant with a long interval will thus have virtually greater weight. But before proceeding to make this correction we may glance at the *sort* of result we may expect, which will not be very different from that obtained from these simple means, since the intervals are roughly about five years.

Table IV.

Approximate Mean P.M.'s in R.A. for five years in units of 0″·03 *or* 0ˢ·00225.

Decl.	6·0.	7·5.	8·5.	9·0.	9·4.
+26°	−18·6	−8·7	+1·5	−0·3	+2·6
+27	− 6·9	−7·2	+0·2	+0·9	+2·5
+29	−15·1	−4·8	−3·5	−1·1	+2·4
Mean	−13·5	−6·9	−0·6	−0·2	+2·5

9. These numbers are sufficient to indicate:

(*a*) The *real* nature of the phenomenon from the fact that there is a sensible accordance between all these zones, which are quite independent.

(*b*) The *sign* of the motion is a *decreasing* R.A. for bright stars relatively too faint.

(*c*) The magnitude of the motion is about 1 unit per magnitude per year, which would give a series of theoretical results, such as

Mag.		6·0.	7·5.	8·5.	9·0.	9·4.
Calculated	...	−15·0	−7·5	−2·5	0·0	+2·0
Observed	...	−13·5	−6·9	−0·6	−0·2	+2·5
O.−C.	...	+ 1·5	+0·6	+1·9	−0·2	+0·5

(The residuals would be improved a little by assuming a different rate for bright and faint stars; but for the present we will put this aside.) This quantity 0″·03 or 0ˢ·00225 per magnitude per year is nearly double the quantity found by Sir D. Gill (see § 4); but it is at any rate of the same order of magnitude.

10. With these indications of the reality of the phenomenon we may proceed to combine our results to the best advantage. There seems no need to keep the results of the different zones separate, and by combining them we shall remove some of the weaknesses made apparent in Table I. The number of plates in each octant will then stand as follows:

TABLE V.

	0^h-3^h	-6^h	-9^h	-12^h	-15^h	-18^h	-21^h	-24^h
Num. early plates	12	23	29	13	29	19	33	38
„ late „	16	27	24	38	23	35	23	12
Mean interval in years	5·2	5·2	4·9	5·3	4·5	4·6	4·1	4·0

which should give a strong enough determination of the quantity throughout the R.A. circuit.

11. In combining the results for different zones weights have been assigned according to the number of *plates*, so as to have a uniform system of weighting for stars of different magnitudes and for the mean dates. The results are given in Table VI. The differences between early and late plates have then been divided by the mean intervals shown in Table V. so as to get the annual P.M.'s shown in Table VII., still expressed in the unit 0″·03 or 0ˢ·00225.

TABLE VII.

Deduced Relative Motions in each Octant.

(The unit is 0″·03 or 0ˢ·00225 per year.)

Octant.	Mag. 6·0.	Mag. 7·5.	Mag. 8·5.	Mag. 9·0.	Mag. 9·4.	Bright.	Gradients (See § 24). Mean.	Faint Stars.
h. h.								
0− 3	−6·3	−5·5	−2·1	−2·6	+0·9	−0·5	−2·07	−3·3
3− 6	+0·7	+0·4	+1·7	+0·4	+0·1	+0·2	−0·09	+1·8
6− 9	+1·4	−2·5	+0·9	+0·9	+1·9	+2·6	−0·81	−1·1
9−12	−2·1	+1·6	−0·4	+0·6	−0·1	−2·5	−0·09	−0·3
12−15	−1·1	−2·2	−0·4	−1·0	+1·3	+0·7	−0·72	−1·9
15−18	+1·5	+0·6	+0·5	+1·5	−1·9	+0·6	+0·45	+2·7
18−21	−0·9	−0·8	−1·4	+0·7	−0·3	−0·1	−0·23	−1·2
21−24	−2·9	−0·8	+0·7	−1·0	+0·3	−1·4	−0·81	+0·4
Mean	−1·21	−1·15	−0·06	−0·06	+0·28	−0·05	−0·55	−0·36

TAB

Mean Results

(The unit is

Octant of R.A.	Interval in Years.	6·0 E.	6·0 L.	6·0 L−E.	7·5 E.	7·5 L.	7·5 L−E.
h. h.							
0− 3	5·2	+74·7	+42·2	−32·5	+66·3	+37·6	−28·7
3− 6	5·2	+36·1	+39·9	+ 3·8	+18·9	+21·0	+ 2·1
6− 9	4·9	+42·4	+49·1	+ 6·7	+38·7	+26·6	−12·1
9−12	5·3	+43·2	+32·1	−11·1	+22·8	+31·2	+ 8·4
12−15	4·5	+36·6	+31·6	− 5·0	+35·8	+25·7	−10·1
15−18	4·6	+44·5	+51·3	+ 6·8	+26·2	+28·9	+ 2·7
18−21	4·1	+47·0	+41·5	− 5·5	+35·5	+32·2	− 3·3
21−24	4·0	+57·8	+46·3	−11·5	+39·8	+36·8	− 3·0

12. How far the mean quantities are accordant with the formula

$$0{\cdot}55 \times (\text{mag.} - 9{\cdot}0)$$

may be seen from the following small table.

TABLE VIII.

Mag.	Obs.	Calc.	O.−C.
6·0	−1·21	−1·65	+0·44
7·5	−1·15	−0·83	−0·32
8·5	−0·06	−0·28	+0·22
9·0	−0·06	0·00	−0·06
9·4	+0·28	+0·22	+0·06

But it seems difficult to regard the quantities O.—C. as accidental. The change is abrupt at about magnitude 8·0 rather than gradual.

13. We shall presently return to the question whether the change is abrupt or gradual; meanwhile we may note that the more careful discussion of the observations has reduced the magnitude of the relative P.M. from the value 1·00 found by the rough computation of § 9 (*c*) to the value 0·55 per magnitude per year: or in seconds of time $-0^{s}{\cdot}0013$ per magnitude per year, which is almost precisely the quantity found by Sir D. Gill (see § 4), *but of opposite sign.*

14. We will now turn to an independent piece of evidence which presented itself in the course of the work. Having occasion to refer to my earlier paper on the Cambridge magnitude equation (*Monthly Notices*, lx. p. 3), my attention was arrested by the paragraphs 11 and 13 concerning the variation of the magnitude equation with R.A. Paragraph 11 runs as follows:—

LE VI.

for all Zones.

0".03 or 0".00225.)

8·5.			9·0.			9·4.		
E.	L.	L−E.	E.	L.	L−E.	E.	L.	L−E.
+26·0	+14·9	−11·1	−2·7	−16·1	−13·4	−31·3	−26·4	+4·9
+10·3	+19·0	+ 8·7	−5·4	− 3·3	+ 2·1	−33·3	−33·0	+0·3
+14·6	+18·8	+ 4·2	−2·4	+ 2·0	+ 4·4	−34·6	−25·2	+9·4
+17·5	+15·2	− 2·3	−9·8	− 6·4	+ 3·4	−24·6	−25·3	−0·7
+16·2	+14·5	− 1·7	−2·3	− 6·7	− 4·4	−42·0	−36·3	+5·7
+10·6	+12·7	+ 2·1	−4·1	+ 2·9	+ 7·0	−23·8	−32·3	−8·5
+21·7	+15·3	− 6·4	+0·9	+ 4·0	+ 3·1	−25·8	−27·1	−1·3
+24·3	+26·9	+ 2·6	+4·0	+ 0·1	− 3·9	−29·5	−28·3	+1·2

"Returning now to the Cambridge personality one important question is, Does it vary with the R.A.? The answer seems to be in the affirmative; but the variation is small compared with the whole amount. It is also rather exceptional in character; and as yet I can suggest no physical reason for it. The personality is rather greater for 21^h-3^h R.A. and for 12^h-15^h R.A. than for the rest of the circuit, and is greater proportionally—*i.e.* the increase is greatest for bright stars.".

[In § 12 of this paper there is an error in the last line but one: *for* $+0^s.013$ *read* $-0^s.013$. The correct sign was used, but the wrong one printed.]

In § 13 of the same paper the actual figures are given as follows:—

Mag.	0^h-3^h. s	3^h-6^h. s	6^h-9^h. s	9^h-12^h. s	12^h-15^h. s	15^h-18^h. s	18^h-21^h. s	21^h-0^h. s
5·0 to 6·9	+·030	−·005	−·015	−·013	+·010	−·005	−·024	+·011
7·0 „ 7·9	+·021	−·014	+·004	−·006	+·008	−·019	−·006	+·004
8·0 „ 8·4	+·010	−·003	·000	+·001				
8·5 „ 8·9	+·006	+·004	·000	−·004				
9·0 „ 9·4	−·010	+·006	−·002	+·007				

15. Now it occurred to me that perhaps the explanation of these differences lay in a difference of date at which the *Cambridge* observations were made. In meridian observing it is a common experience to find certain parts of the catalogue "cleared off" before others; and any systematic proper motions might thus introduce apparent systematic errors. The dates of the Cambridge observations were examined in two ways.:

(A) The mean date was formed for each catalogue page (of fifty stars of all magnitudes) which contained the beginning of a new hour, *i.e.* the pages containing $0^h\ 0^m$, $1^h\ 0^m$, $2^h\ 0^m$, and so on. The mean of the *four* pages, $0^h\ 0^m$, $1^h\ 0^m$, $2^h\ 0^m$, $3^h\ 0^m$, was

considered to represent the approximate mean date of the observations in the octant $0^h - 3^h$; and so for other octants.

(B) The epochs of observation for all the bright stars (5·0 to 8·0) in each octant were set down and the mean taken.

The results are given in Table IX., wherein is also given the mean date of the Oxford plates used for the paper above quoted. It will be seen that the variations of date are chiefly in the Cambridge observations, and are small. As the discrepancy under consideration is greatest for bright stars, it seems preferable to adopt column (B) in forming the interval between the Cambridge observations and the Oxford plates during which the effects of P.M. will accumulate.

TABLE IX.

Dates of the Observations used in the Paper of 1899 November.

h h	Cambridge (A)	Cambridge (B)	Oxford	Oxford −(B) y	Diff. from Mean
0– 3	1880·8	1880·5	1896·3	15·8	−1·3
3– 6	80·5	79·5	96·3	16·8	−0·3
6– 9	80·0	78·2	95·8	17·6	+0·5
9–12	78·5	78·4	96·3	17·9	+0·8
12–15	80·8	79·4	95·6	16·2	−0·9
15–18	80·2	79·5	96·3	16·8	−0·3
18–21	80·1	77·3	95·7	18·4	+1·3
21–24	81·1	78·0	95·2	17·2	+0·1
Mean	...	1878·8	1895·8	17·1	...

16. Now if we arrange the quantities quoted in § 14 according to the value of the interval we get the following result:—

TABLE X.

Interval (Diff. from Mean)	Octant	Observed Mag. 5·0 to 6·9	Observed Mag. 7·0 to 7·9	Calculated Mag. 5·0 to 6·9	Calculated Mag. 7·0 to 7·9
	h h	s	s	s	s
−1·3	0– 3	+·030	+·021	+·005	+·003
−0·9	12–15	+·010	+·008	+·003	+·002
−0·3	3– 6	−·005	−·014	+·001	+·001
−0·3	15–18	−·005	−·019	+·001	+·001
+0·1	21–24	+·011	+·004	·000	·000
+0·5	6– 9	−·015	+·004	−·002	−·001
+0·8	9–12	−·013	−·006	−·003	−·002
+1·3	18–21	−·024	−·006	−·005	−·003

17. There certainly seems to be some ground for the explanation of these quantities, in part at any rate, by the relative

proper motions found above. Under the heading "calculated" are given the quantities deducible on the assumption that the relative P.M. is

$0^s{\cdot}00124$ per magnitude per year.

If we add together the results for which the calculated effect is positive, and those for which it is negative, we get

	Mags. 5·0 to 6·9		Mags. 7·0 to 7·9	
Observed . .	+·030	−·052	−·004	−·008
Calculated . .	+·010	−·010	+·007	−·006

The total sum of positive groups is $+^s{\cdot}026$ observed and $+^s{\cdot}017$ calculated; of negative groups $-^s{\cdot}016$ observed and $-^s{\cdot}060$ calculated. The accordance is thus far from perfect.

18. A better accordance is obtained if instead of assuming the same relative P.M. throughout we take separate results for each octant. But it is unprofitable to pursue this line of inquiry further at this point, for there is a disturbing cause affecting these figures. The clock-star list in use at Cambridge was changed on 1883 January 1; and Mr. Hinks has shown (in *Monthly Notices*, lvii. p. 474) that there was a resulting apparent increase of the Cambridge R.A.'s by $+0^s{\cdot}030$.

But his discussion takes no account of the present phenomenon, and may require modification in the light of it. The inquiry should be reopened and will need an elaborate piece of work which cannot be undertaken just at present. We must be content with the qualified confirmation of our results indicated in Table X.

19. Returning then to the main conclusion of § 13—

In declination + 25° *to* + 30° *the R.A.'s of the brighter stars are decreasing relatively to the fainter* (*between the limits of magnitude* 5·0 *to* 9·5) *at the rate of* $0^s{\cdot}00124$ *per magnitude per year*—

and comparing this with the conclusion of Sir D. Gill, that

In declinations −40° *to* −52° *the R.A.'s of the brighter stars are increasing relatively to the fainter* (*between the limits of magnitude* 4·0 *and* 8·0) *at the rate of* $0^s{\cdot}0014$ *per magnitude per year*,

the question arises, whether these two facts concerning particular belts of the heavens give us any information as to the general nature of the phenomenon. It seems to me that the difference of sign proves conclusively that we are *not* in the presence of what Sir D. Gill calls "an apparent rotation of the brighter fixed stars as a whole with respect to fainter stars as a whole." If there is such a rotation about any axis whatever we may resolve the minute effects observed hitherto into effects due to the rotations about two axes, one parallel to the axis of the Earth and the other perpendicular to it. The latter will

produce zero effect in R.A. for the mean of a zone of stars of the same declination (assuming the system of equal weighting adopted by Sir D. Gill and also in the present paper); while the former would produce a rotational effect which should have *the same sign for all zones*. The direct contradiction of sign in the northern and southern hemispheres seems to put this idea of a general rotation out of court.

20. Before proceeding to make any suggestion in place of it, let us consider again what is involved in the system of equal weighting in R.A. adopted by Sir D. Gill. He adopted it to eliminate the effect of the Sun's motion through space. I may perhaps quote a few words from a letter of his to me (dated 1902 Sept. 10) where he puts his point clearly.

"The parallactic motion due to the Sun's motion through space is:

$$\mu_\alpha = + V\varpi \cos D \sec \delta \sin (\alpha - A)$$
$$\mu_\delta = - V\varpi \{\cos \delta \sin D - \sin \delta \cos D \cos (\alpha - A)\}$$

where V is the Sun's velocity expressed in radii of the Earth's orbit, A and D the R.A. and Decl. of the point in the heavens towards which the Sun is moving, and ϖ the annual parallax of a star whose R.A. and Decl. are α and δ.

"Now μ_α disappears in the mean proper motion of stars of the same Decl. Symmetrically distributed in R.A. μ_δ does not; hence the comparative simplicity of discussing R.A. only. Of course the complete discussion must involve the discussion of the declinations, but the result can only be derived by successive approximations."

21. Now, it is only true that "μ_α disappears in the mean proper motion of stars of the same Decl. symmetrically distributed in R.A." *if* ϖ *remains constant*; but if ϖ varies the mean will not generally be zero. Sir David Gill has selected stars of constant *magnitude*, but does it follow that they have a constant *parallax*? We have very little information on the point, and what we have is rather against this conclusion than for it. Not to speak of individual or exceptional cases, we have learnt, from the work on the "Cape Photographic Durchmusterung," that there is a systematic difference between the visual and photographic magnitudes of stars, depending on their galactic latitude. Is it the visual or the photographic magnitude which indicates the parallax? It is true the difference is small compared with either; but this is only one piece of evidence of *structure* in the universe, and directly the idea of structure is introduced we must admit that the parallax of a star will depend not only on its magnitude but on its *position*. If ϖ varies with δ and α the mean value of μ_α is no longer zero on the system of equal weights.

22. It seems possible, then, that Sir David Gill has indicated, not a general rotation in the universe, but a method of gauging its detailed structure; a method of elementary sim-

licity and of the gravest importance. We must set to work to determine the gradient of relative proper motions as we pass rom bright to faint stars in every quarter of the heavens, and tudy the results as they accumulate. In particular it would eem almost imperative that, as soon as possible after the Astrographic Catalogue, or any portion of it, is completed, it should be ecommenced with a view to the determination of these proper notions.

23. But although our present information is scanty, it is, perhaps, not too early to anticipate a possible reason for the difference of sign found in the N. and S. hemispheres. The apex of the Sun's motion is at 18^h R.A. The Milky Way rises highest into the northern hemisphere about 0^h, where the effect of the parallactic motion is in the direction of increasing R.A.; while stars about 12^h, with decreasing R.A., are at nearly the limit of distance from the galaxy. These conditions are, of course, inverted in the southern hemisphere.

24. Let us consider in detail whether this may afford the clue to the cause of the phenomena under consideration. Returning to Table VII. the last three columns give three "gradients" formed as follows: Subtracting from the mean of the results for magnitudes 6·0 and 7·5 the mean of the three results for 8·5, 9·0, and 9·4, and dividing the difference by 2·2 (the difference of the mean magnitudes) we get the mean relative P.M. for one magnitude, which is called the mean gradient. But as there seems some reason to suppose that the gradient is not uniform two other columns have been formed: that for "Bright" stars by comparing the results for 6·0 and 7·5 and dividing by 1·5; and that for "Faint" stars by comparing 8·5 and 9·4 and dividing by 0·9. The accidental errors of these columns are of course larger than that for the mean.

25. Now if we are to explain these relative P.M.'s in terms of the Sun's motion in space, we must consider the parallactic factors for the eight octants. In the expression given above

$$\mu_\alpha = V\varpi \cos D \sec \delta \sin (\alpha - A)$$

we assume

$V \cos D$ constant for the present

[It is of course possible that $V \cos D$, which is the motion of the Sun *relative to the stars*, may vary for different regions of the sky; and in fact some general suppositions of this kind have come under consideration in the course of the work, but were discarded later.]

and $\sec \delta$ is constant for our zone

Hence we need only consider the factor

$$\varpi \sin (\alpha - A)$$

If we divide the "gradient" by $\sin (\alpha - A)$ we get quantities

proportional to ϖ, which now represents the *difference of parallax per magnitude*. This division is performed in Table XI., and the galactic latitude of the group is added for comparison.

TABLE XI.

Octant. h. h.	Sin (a−A).	Differences of ϖ per mag. 6·0−7·5.	Mean.	8·0−9·4.	Galactic Latitude. °
0−3	+·9	−0·6	−2·3	−3·7	−34
3−6	+·4	+0·5	−0·2	+4·5	−13
6−9	−·4	−6·5	+2·0	+2·8	+22
9−12	−·9	+2·8	+0·1	+0·3	+61
12−15	−·9	−0·8	+0·8	+2·1	+80
15−18	−·4	−1·5	−1·1	−6·8	+40
18−21	+·4	−0·2	−0·6	−3·0	+ 2
21−24	+·9	−1·6	−0·9	+0·4	−25

26. Looking now first at the column "Mean" (the others being affected by larger accidental errors), let us arrange the results in order of galactic latitude (taking no account of sign in this latitude).

Gal. Lat.	+2°	−13°	+22°	−25°	−34°	+40°	+61°	+80°
Mean	−0·6	−0·2	+2·0	−0·9	−2·3	−1·1	+0·1	+0·8

But for the positive sign at +22° these would fall into fairly regular sequence, all the quantities near the galaxy being negative and those near its poles positive; unless the + sign at +22° is an indication (allowing for accidental errors) of a return to a positive sign close to the galaxy.

27. The physical meaning of these figures would be, that within 24° of the Milky Way, and also near its poles, a bright star is nearer us on the average than a faint; but that for intermediate galactic latitudes (25°–50° say), and for a certain range of magnitudes, the *faint stars are actually nearer us than the bright*. And we have now to consider how this could be explained.

28. First consider a number of stars of the same intrinsic brightness (for brevity say the same *size*) scattered uniformly through space. When regarded from any view-point the apparent brightness of any of them varies as $1/(\text{dist.})^2$; or if 2·512 be denoted by a^2, the magnitude by m, and the distance by d

$$a - 2m = \text{brightness} = C^2 d^{-2}$$

$$\text{or } d = Ca^m$$

where C is a constant.

The total number of stars within a distance d varies as d^3, or

a^{3m}, and the number between magnitudes m and $m+1$ thus varies as $a^{3m+3}-a^{3m}$), which itself varies as a^{3m}. Hence we have for stars of magnitude m

$$\text{Parallax} = Aa^{-m}$$
$$\text{Number} = Ba^{3m}$$

where A and B are constants depending on the number of stars per unit volume and the intrinsic brightness of each.

29. Secondly, suppose we have two such systems superposed, the constants for one being A_1 B_1, for the other A_2 and B_2. Then we have for stars of magnitude m

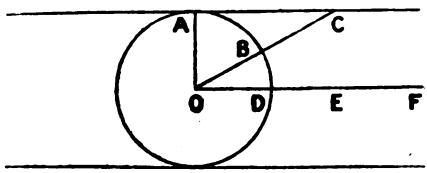
$$B_1a^{3m} \text{ stars of parallax } A_1a^{-m}$$
$$B_2a^{3m} \quad ,, \quad ,, \quad A_2a^{-m}$$

So that the *mean* parallax for magnitude m is now

$$\frac{B_1A_1+B_2A_2}{B_1+B_2}a^{-m} = A_3a^{-m}$$

i.e. it follows the same law of decrease with magnitude as before only with a different constant A_3 instead of A_1 or A_2, and intermediate between them, since B_1 and B_2 are both positive.

30. Now imagine two systems of stars to be superposed, one a set of small (*i.e.* intrinsically faint) stars uniformly scattered round the Sun in all directions as represented by the circle ABD, the Sun being at O.



Let the central plane of the galaxy be in the direction ODEF, and suppose the galaxy to be a superposed system of large stars (*i.e.* intrinsically brighter than those of the "solar cluster," as we may call the first set perhaps).

Consider the relation between brightness and parallax along three radii, OA, OBC, ODE.

Along OA we have both systems freely mixed, and the relation between magnitude and parallax will follow the usual law.

$$\text{Mean parallax} = A_3a^{-m}$$

where A_3 is, as shown above, intermediate between A_1 and A_2 ($A_1 > A_2$).

Along OBC, however, the stars are only mixed as far as B; and from B to C we have some *large stars* which are thus

reckoned as near us. In fact there is a discontinuity in the law connecting magnitude and parallax. We start with a series

$$A_3 \quad A_3a^{-1} \quad A_3a^{-2} \quad A_3a^{-3} \ldots A_3a^{-r}$$

and we must ultimately change to the series

$$A_2a^{-(r+1)}, \quad A_2a^{-(r+2)}, \text{ \&c.}$$

where A_2 is less than A_3.

So that though the early terms of the series decrease, and the later terms will ultimately decrease, we have near a certain magnitude r an *increase*, viz.

$$A_2a^{-(r+1)} > A_3a^{-r}$$

which will be the case provided

$$A_2 > aA_3, \text{ i.e.} > 2{\cdot}512\ A_3.$$

An abrupt change at a definite magnitude is of course only taken for illustration. The discontinuity will no doubt be spread over several magnitudes; but it is clear that we may in this way get, for a limited range of magnitudes, an *increase* of parallax with decreasing brightness instead of the usual *decrease*.

31. Finally consider the radius ODEF. To make the explanation accord with what has been assumed above, we must show cause why there should be a return to the normal state of things in directions near the galaxy itself. Now the existence of the anomaly depends upon the inequality

$$A_2 > aA_3$$

and from above we have

$$A_3 = \frac{B_1A_1 + B_2A_2}{B_1 + B_2}$$

B_1 and B_2 being proportional to the numbers of stars of each class. As we approach the galaxy we include more stars of the galactic type, and hence we may assume that B_2 increases; so that A_3 approaches nearer A_2, and the inequality no longer holds.

32. This, then, is the rough suggestion for the phenomena observed. It seems worth putting forward as a "working hypothesis," which can be at once tested in several ways, and especially the proper motion in *declination* must be examined for the same plates as have been examined above in R.A.

But this must be deferred to a future paper. Meanwhile the results obtained are so interesting that it seems desirable to publish them at once; and I put this hypothesis along with them, not as fully established, but as one with which it is desirable to compare future results, until it is definitely contradicted by any of them. The former hypothesis of Sir David Gill, of a general rotation of the bright stars with respect to faint stars, turns out

if the results above given may be accepted) not to be well ounded; but I would be among the first to be grateful to him or enunciating it, since it was the means of drawing my attention t once to a line of work which seems likely to bear fruitful esults.

And I will venture to add here another word or two of a ersonal kind. In No. 517 of the *Astronomical Journal* Professor Lewis Boss called attention to the fact that in determining he Cambridge magnitude equation I had treated proper motions s accidental errors, which would disappear in the mean of a umber of stars. "Unless this statement is surrounded by everal qualifications," wrote Professor Boss, "it is by no means orrect," and he went on to specify the qualifications, among which considerations of the Sun's parallactic motion were prominent. Some misunderstandings of what had actually been done in the Oxford work, and, on my part, of what Professor Boss really meant, gave rise to a discussion which turned out to be irrelevant to the real issue (*Astronomical Journal*, Nos. 519, 521, 523). It has been, I hope, satisfactorily closed. But now that I properly understand the real meaning of Professor Boss's remarks with regard to the parallactic motion, it gives me peculiar pleasure to be among the first to confirm their soundness and value in a new way.

A Note relating to the Preservation of Negatives.

By F. A. Bellamy.

Some weeks ago I had occasion to examine a negative of a comet taken in 1899, and upon withdrawing it from its envelope, similar to those used at the University Observatory, Oxford, for storing plates taken for the Astrographic Catalogue, it was immediately noticed by Mr. H. C. Plummer and myself that a representation or impression of the description of the negative written outside the thick envelope had been conveyed to the gelatine film, and almost every letter and figure—though blurred in character, much as a heavily written word would appear on blotting-paper immediately used—could be read *from the plate*. It should be noted that no mark is visible on the *inside* of the envelope to show that the ink had soaked through.

I have since examined a large number of our plates, and I have, I am pleased to state, found very few cases; I may say in general terms that no plate which apparently had a short development and those taken on dark nights—in fact, those that had a bright, clear appearance, and upon which the stars and réseau lines stood in relief, as in the carbon process—showed any sign of this transmitted writing; but the plates that did show it

were in every case, I believe, rather dense in character, either by a light sky, long development, by light getting to the plate before development, or by the old age of the plate before being exposed, especially those packed with sheets of paper between the plates. The ink used was always Stephen's Blue-black or Draper's Dichroic, and was written usually, if not always, on the envelope before the plate was put in. Some words as to when the plate was measured, or other notes, are added from time to time.

In view of the large quantity of plates that are being used in modern astronomy and stored in envelopes for future use it seems desirable to call astronomers' (and others') attention to this small matter, and to use every precaution to prevent any deterioration of negatives. Damp and an undue amount of sunlight are the greatest enemies to the gelatine film of a negative, but certainly by neither of these causes have our plates suffered at Oxford.

May the cause of this marking, not by bleaching, but by staining, be due to a strong acid or chemical used in the manufacture of the ink, or perhaps that combining with the chloride of lime, from which very little modern paper seems free?

For ordinary negatives the best precaution would undoubtedly be to varnish them, but for negatives required for measurement it is not to be recommended, as there are not many who could frequently flow the varnish over the plate without getting a ridge or overlap of varnish, either of which would tend to distort the image of a star or réseau line.

Nearly twenty years ago (1884 or 1885), some time after I first used the gelatine dry plate instead of the wet collodion process, I well remember spoiling some ordinary negatives by merely packing them for a short time with pieces of printed paper between them, and I could have read most of the printing impressed upon them. I believe I still possess some of these plates. Things of this kind one does naturally by inexperience, especially with a new article—as the commercial dry plate then was—and I have not been entrapped to treat negatives in that way since; but what I have made the subject of this short note is, I believe, new, and one that also requires attention being paid to it.

London: 1902 *Dec.* 12.

Note on Binding together Réseaux and Plates.

By J. A. Hardcastle.

It seems probable that réseaux will have to be laid on to photographic plates constantly in the near future for two sufficient reasons: (1) A réseau much facilitates measuring a

ate ; (2) a very large number of plates, *e.g.* all those hitherto ken in America, have no réseau impressed on them before velopment. In view of this fact it cannot be superfluous to put record a piece of recent experience in connection with binding seaux on to negatives.

It is not an easy matter to bind a plate bearing a réseau to a gative with complete rigidity, and it is on this point that a ord of caution seems necessary. No binding, however secure appearance, should be subjected to strain. In the particular stance on which this note is based it was found that, whether om damp or from other cause, the grip by which the plate is ld firm in the measuring machine caused one plate to slip over e other. It occurred in the course of Mr. Saunder's work in e measurement of lunar photographs (see *Monthly Notices*, l. lx., p. 174, and vol. lxii., p. 41). The photographs we have been easuring were taken at Paris and have no réseau on them. he size of the Moon on these plates is about $6\frac{1}{2}$ inches, while the seau was less than 6 inches square, consisting in fact of 31 lines each direction 5 mm. apart. In the plate in question the base was but little over half-moon, and so it was possible to ver the whole visible moon with the réseau by placing the minator diagonally. The corners of the negative were trimmed f, but the plates were eventually bound together with the edge one projecting slightly on one side and the edge of the other ojecting slightly on the opposite side. The risk of displacement would, of course, have been considerably diminished had the me plate projected on all four sides, but it was desired to produce previous measurements and the advantages seemed outweigh the risks. The binding was extremely strong, but it came evident eventually that a translation amounting to ·075 m. (·003 in.) and a rotation of 52″ had taken place.

Although the larger part of this shift was proved to have ken place on one particular day in September, during which the late was not taken from the measuring machine, the remainder the displacement (about ·03 mm.) occurred apparently more or ss gradually in August.

The only possible method of detecting such a gradual displacement is the daily record of the positions of four fiducial arks, one at each corner of the negative. Such marks may be ade on the film of the negative with a needle-point before inding, and should be read at the beginning and end of each ay's work.

For the binding seccotine would be preferable to ordinary um, and a touch of shellac might be used between the films at ch corner.

Another difficulty in using réseaux bound on to negatives ises from the fact that the surfaces of the glass are not plane, nd accordingly contact is not universal over the whole negative. esides the obvious risk of parallactic displacement of a réseau-ne relatively to the negative there has been further found a

change of position of réseau-lines when the direction source of illumination changes. It has accordingly been necessary to use an adjustable clamp, to press the two si into contact in the neighbourhood where measurements are taken. The use of plate glass would obviate the neces this precaution; but the fact remains that it has not bee nor have réseaux been impressed on the negatives, and accordingly a matter of great interest that experience in c with the plates actually in existence should be recorded.

Photographic and Visual Magnitudes of α Orionis.

By W. H. Robinson.

(*Communicated by A. A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Ob*

Since Mr. Packer's announcement concerning the incr brightness of *α Orionis* several photographs of the region sky including this star have been secured, the half-plate used being that employed last year in the determination photographic magnitude of *Nova Persei*. The results of the investigation were published in the *Monthly Notices* R.A.S., vol. lxii., Nos. 3 and 6. In No. 3 the write attention incidentally to the chemically active quality light of the new star on 1901 March 9, and contrasted the non-actinic character of the light of *α Orionis*, which time was visually similar to it in colour. This photogra now become additionally useful, being included with the photographs in the following discussion.

In the present paper the methods of measurement of and reduction of results for *α Orionis* are precisely sim those adopted for *Nova Persei*.

Nine comparison stars have been selected in determini scale of brightness. The names of these, with their (Harvard) magnitudes and mean measured photographic ness, are as follows :—

Name of Star. *Orionis.*	Tabular Magnitude.	Scaled Photographic Brightness (Means).	Name of Star. *Orionis.*	Tabular Magnitude.	S Phot Bri (?
γ	1·75	20·0	λ	3·5	
ε	1·75	28·2	σ	3·75	
ζ	1·9	28·4	A	4·4	
δ	2·5	31·1	ϕ^1	4·4	
η	3·45	50·3			

Plotting the above values on square-ruled paper, and d

smooth curve through them, the magnitude equivalents for arbitrary scale were found to be:

Scale.	Magnitude Equivalent.	Scale.	Magnitude Equivalent.
20	1·52	45	3·38
25	1·87	50	3·76
30	2·26	55	4·13
35	2·64	60	4·50
40	3·01		

The equivalents were then adopted for forming the photographic magnitudes of *α Orionis*, which, together with the visual magnitudes, are exhibited in the following table. The visual magnitudes are only approximate, since they depend upon comparison with two stars only, viz. *Capella* and *Rigel*, which differ greatly from *α Orionis* in colour and position. Their widely differing zenith distances rendered necessary the application of corrections for atmospheric absorption, the formula adopted being

$$A = 0{\cdot}25 \text{ (sec. } Z - 1).$$

The small differential residuals of these corrections have been allowed for in column 5.

Ref. No.	G.M.T.		Scaled Readings.	Photographic Magnitudes.	Visual Magnitudes. *Corrected* for Atmospheric Absorption.	Visual Magnitudes. *Uncorrected* for Atmospheric Absorption.
1	1901. Mar. 9	h 9½	38·8	2·92*	(0·91)†	(0·91)†
2	1902. Oct. 22	h 12½	35·6	2·68	...	...
3	Nov. 8	11−	36·9	2·78	0·23	0·25
4	8	11+	37·4	2·82	0·23	0·25
5	12	12	38·3	2·88	0·27	0·25
6	28	11	...	...	0·27	0·25
7	Dec. 1	11	...	...	0·27	0·25
8	3	10	...	...	0·29	0·29
9	4	11	...	...	0·29	0·29
10	6	11	38·6	2·91	0·29	0·29

Remarks.—1. Photographed on same plate with *Nova Persei*. The values in cols. 5 and 6 marked thus ( )† are taken from Harvard Photometry. 2. Light clouds passing at times; moonlight. 3, 4, 5. To the naked eye *α Orionis* is certainly brighter than *Rigel* and distinctly fainter than *Capella*. 8. *α Orionis* is not so bright to-night to the naked eye; it is nearer *Rigel* than *Capella* in magnitude. 9, 10. *α Orionis* between *Capella* and *Rigel* in brightness, nearer *Rigel*.

Erratum.—P. 199 of vol. lxii., *α Orionis*. Photographic magnitude. For 3·20 *read* 2·92, the latter being the definitive value, the former only a provisional one.

During the period 1902 Oct.–Dec. the observers at Oxford have several times noted an unusually crystalline image of *α Orionis*. The star *Capella* has generally been observed by the writer to be about one magnitude brighter than *Rigel*. Allowing for the effect of atmospheric absorption, a difference exists of about 0·6 or 0·7, which is sensibly greater than that given in the Harvard Photometry, viz. 0·14. Within small limits these two comparison stars are probably variable, as suggested by W. Struve and Argelander respectively, and by others.

It will be seen in the preceding table that between 1901 March 9 and 1902 October 22 the photographic magnitude of *α Orionis* had increased, but only slightly. Since October 22, however, a gradual decline appears to have set in. The evidence afforded by the visual estimates, and by the remarks appended to them, also confirms not only the brightening between the two first dates, but the slight decrease which appears to have taken place subsequently.

Radcliffe Observatory, Oxford:
1902 Dec. 10.

Cape Double Star Results, 1902. By R. T. A. Innes.

(*Communicated by Sir David Gill, K.C.B., F.R.S., H.M. Astronomer.*)

The winter was a very wet one, so that very few nights were available for double-star work. Through leave of absence, observations ceased early in August. All the measures were made with the Repsold micrometer on the 18-inch refractor. In the cases of a few newly discovered pairs estimates only have been secured: these were generally made at the 7-inch refractor.

A few measures previously omitted are included.

The measures of α Centauri will be found on p. 81.

The screw-value used in 1902 is 17″·600.

The colour scale used and the general arrangement of the results are as in 1901. See *Monthly Notices*, vol. lxii. pp. 470–484.

Incidentally it was found that the star G.P.Z. 7641, mag. 8·7, occupies the centre of a round nebula of about 3′ diameter, and it is therefore a nebulous star. Its position is:

	h	m	s	°	′
1860	11	5	32	−75	51·2
1875	11	6	1	−75	56·3
1900	11	6	49	−76	4·4

Mag. in the C.P.D. = 8·6.

ıebula *h* 3413 = N.G.C. 4976 is identical with C.P.D.). 5305, (1860) $13^h\ 0^m\ 38^s - 48°\ 45'{\cdot}4$.

Mag.	R.A. 1900. h m	S. Dec. ° ′	1902·±	Pos. Angle.	Dist.	Diff. of Mags.	Colours A, B	No of Nights.	Remarks.
... 7·3	1 12	69 21	15	208·0	0·96	0·6	...	1	
... 4·9	1 12	69 24	15	352·8	5·00	...	3, —	1	1
... 7·9	2 33	88 50	...	204·9	...	...	...	2	2
... 7·2	2 37	59 59	15	143·5	0·3 ±	0·2	0, 0	1	
... 6·7	2 49	41 48	15	295 ±	15 ±	6·8	...	1	3
... 8·2	3 16	63 26	14	358·0	3·93	2·5	...	1	22
... 9·0	3 42	40 29	14	211·4	3·78	1·1	...	1	4
... 5·3	4 13	62 27	15	253·8	8·43	4·0	4, *b*	2	
... 7·8	4 23	24 41	2	330 ±	0·7 ±	0·5	...	1	5
... 6·4	5 21	56 15	0	60 ±	0·5 ±	0·1	...	1	6
... 7·0	6 11	29 34	30	45·1	5·90	...	...	1	
... 8·5	6 12	49 5	30	63·5	5·32	...	4, *b*	1	
... 7·0	6 13	22 40	30	20·1	35·1	...	2, —	1	
6... 9·4	6 19	73 26	1	260 ±	2 ±	1·0	...	1	7
... 7·0	6 31	33 56	30	33·3	1·09	0·1	2, 2	1	
... 5·0	6 36	48 8	30	319·4	12·9	...	4, *b*	1	
... 6·3	6 54	35 23	30	207·6	...	...	...	1	8
... 7·5	6 57	25 30	16	147·0	3·35	2·4	1, 5	2	
... 8·0	7 8	60 25	21	179·1	poor	...	...	1	
) ... 7·5	7 8	56 12	01	219·9	1·42	1·0	...	1	
... 4·9	7 12	23 8	36	60·6	27·3	...	...	2	9
71] 7·7	7 31	66 58	11	192·3	3·66	...	4, *b*	2	
... 8·8	7 35	48 27	35	138·5	1·04	1·0	...	1	
... 5·9	7 36	37 55	35	150·7	1·59	...	...	1	10
... 7·4	7 36	43 3	32	214·5	0·91	0·4	0, 0	2	
... 9·5	7 37	29 53	32	195·7	1·81	0·6	...	2	
... 7·5	7 39	42 20	35	124·9	1·14	1·6	...	1	
... 3·8	7 43	72 22	01	116·0	17·1	...	...	1	
... 5·3	7 44	38 16	35	83·6	10·5	4·0	...	1	
... 8·5	7 45	44 18	35	87·2	3·08	1·2	...	1	
... 4·7	7 49	38 36	35	nil	...	...	...	1	36
... 8·2	7 57	40 18	35	119·4	0·78	2·5	...	1	
... 9·2	7 58	34 12	26	12·9	3·53	2 7	...	2	
... 9·3	7 59	34 17	08	339·1	2·92	0·3	0, 0	2	
... 7·5	8 3	39 49	27	77·2	0·64	1·0	3, 3	1	

Star.	Mag.	1900. R.A.	1900. S. Dec.	1902·±	Pos. Angle.	Dist.	Diff. of Mags.	Colours A.B.	No. of Nights.	
		h m	° ′		°	″				
Innes 191 ...	8·7	8 5	41 37	35	199·8	0·99	0·7	...	1	
„ 166 A-B	9·0	8 11	52 4	16	239·9	2·16	2·0	...	1	
„ „ A-C				„	277·2	8·40	3·0	...	1	
Corboba (76)	8·2	8 13	34 33	26	148·2	2·02	0·5	...	1	1
Innes 9 ...	6·8	8 16	73 30	36	308·9	0·78	0·1	2, 2	1	1
„ 194 ...	9·0	8 17	59 53	36	132·7	1·33	1·0	3, *b*	1	
„ 393 ...	6·5	8 19	26 2	26	221·8	3·26	7·5	3, —	2	
B Velorum ...	4·8	8 19	48 10	36	141·4	0·89	1·5	...	1	
Brisb. 2035...	7·5	8 24	40 55	26	107·1	6·15	2·5	...	2	
Innes 394 ...	8·0	8 26	38 16	36	189·4	0·70	0·7	...	1	
„ 313 ...	7·2	8 27	41 11	36	216·2	3·79	2·0	4, B	1	
„ 168 ...	6·9	8 27	44 24	36	79·0	3·34	3·5	...	2	
h 4106 ...	7·8	8 28	36 21	26	146·0	6·30	2·0	3·5, *b*	2	1
h 4107 ...	6·6	8 28	38 44	26	328·9	4·36	...	2, *b*	2	
Innes 11 ...	6·5	9 12	45 8	27	269·9	0·94	1·5	2, 2	1	1
„ 12 ...	5·4	9 18	74 28	25	259·4	0·3 ±	...	...	1	1
ψ Argûs ...	3·5	9 27	40 2	21	338·8	0·48	...	...	4–1	16
C.Z. 9h 2351	8·8	9 30	43 52	26	169·7	4·46	0·1	...	2	1
Innes 350 ...	8·0	9 34	67 46	18	179·2	1·68	...	...	2	
λ 115 ...	5·5	9 34	53 13	21	168·4	0·78	...	3, 3	3	
Innes 360 ...	8·9	9 34	66 50	12	184·4	5·16	...	2, *b*	1	
„ 202 ...	7·0	9 35	39 10	31	175·3	1·09	2·0	2, *b*	1	
„ 203 ...	8·2	9 36	62 6	25	314·3	0·3 ±	...	...	1	1
„ 320 ...	8·6	9 36	66 15	12	47·9	1·09	...	...	1	
Rumker 12 ...	6·7	9 53	68 43	36	213·0	9·46	1·5	...	1	
φ Argûs ...	3·7	9 53	54 6	40	9·0	37·3	...	...	1	
Innes 322 ...	9·0	9 55	62 5	40	66·2	1·87	1·0	...	1	
„ 290 ...	9·2	9 59	59 36	44	284·3	1·14	1·0	...	1	1
C.P.D. 1699	9·6	9 59	59 28	42	92·5	5·26	0·1	...	2	1
„ 1718	9·2	9 59	59 31	42	274·2	2·27	1·5	...	2	1
Innes 291 ...	7·2	9 59	70 15	38	321·3	1·07	2·5	2, *b*	2	
„ 292 ...	7·3	10 0	27 54	40	210·4	0·66	0·3	3, —	1	
„ 293 ...	6·9	10 1	27 43	40	327·5	0·54	...	...	1	
„ 173 ...	5·2	10 2	46 53	31	53·7	0·57	2·8	3, —	1	
„ 13 A–B	6·4	10 7	68 12	47	326·3	0·75	0·1	3, 3	2	
„ AB–C				50	40·3	25·8	...	...	1	
„ 361 ...	8·5	10 9	46 59	30	135·4	4·77	2·0	3, —	2	

r.	Mag.	1900. R.A. h m	1900. S. Dec. ° ′	1902·±	Pos. Angle. °	Dist. ″	Diff. of Mags.	Colours A.R.	No. of Nights.	Remarks.
ll 139...	7·2	10 12	66 47	45	333·5	2·12	1·8	4, *b*	1	
10h 889	8·7	10 13	41 1	38	338·8	2·69	0·7	*y*, *b*	2	21
206 ...	8·5	10 14	22 40	26	328·0	1·01	...	...	2	
207 ...	8·5	10 14	32 43	43	322·4	2·27	0·3	...	2	
ll 141...	7·7	10 17	66 40	47	45·8	1·93	1·2	*y*, *b*	2	
) A—B	7·5	10 20	43 44	47	26·5	0·78	1·1	...	2	
AB—C				50	22·0	24·2	6·5	...	1	
) A—B	7·5	10 20	38 4	47	137·0	0·77	0·1	2, 2	2	
AB—C				50	126±	20±	7·5	...	1	
) ...	7·7	10 23	38 12	47	236·1	0·95	2·5	...	2	22
...	7·2	10 25	48 29	14	221·4	5·31	...	2, *b*	2	23
...	8·4	10 28	61 4	...	50·3	1·00	2·0	...	2	24
...				46	46·0	0·98	1·5	...	2	
...	9·0	10 28	61 17	45	343·9	4·98	2·0	...	1	
ba (24)	7·4	10 31	57 10	28	238·4	5·17	2·3	4·5, B	2	25
74 ...	8·5	10 32	63 37	28	231·7	2·96	1·4	—, *r*	2	
175 ...	7·7	10 32	47 20	28	156·5	1·93	3·2	...	2	
10h, 3 A—B	9·0	10 34	64 51	28	14·3	0·59	0·1	...	2	26
AB—C				28	6·1	5·07	0·2	...	2	
397 ...	8·7	10 40	36 21	25	352·1	1·24	1·0	...	1	
398 ...	8·8	10 42	56 48	34	235·2	4·52	...	...	2	
ume-tis ...	5·5	10 44	79 56	28	60·0	0·69	0·3	4, 4	2	
) ...	8·9	10 44	40 55	47	344·5	11·0	0·5	...	1	
1273 ...	8·5	10 49	62 33	38	203·3	2·33	0·2	4, 4	2	27
l 164...	7·0	10 55	60 47	44	81·7	3·78	3·5	3, —	1	
212 ...	7·0	10 58	81 1	31	151·3	0·73	...	...	1	
A. 166 arin.)...	9·7	11 3	58 10	34	221·3	2·85	2·0	...	2	28
213 ...	8·0	11 6	32 1	36	125·9	0·82	2·5	...	1	
...	6·8	11 11	47 22	40	67·4	23·0	3·3	...	2	29
2224	9·6	11 17	61 29	48	34·5	1·11	0·5	...	1	30
76 ...	9·5	11 22	30 11	33	50·5	7·06	0·5	...	1	
834 ...	7·7	11 33	60 56	51	117·7	1·32	2·7	...	2	31
829 A—B	7·2	11 34	62 49	54	94·1	0·53	0·0	3, 3	3	31a
„AB—C				54	359·6	1·66	3·0	...	3	
„AB—D				56	323·2	9·48	5·0	...	2	

Star.	Mag.	1900. R.A.	1900. S. Dec.	1902·±	Pos. Angle.	Dist.	Diff. of Mags.	Colours A.B.	No. of Nights.	Remarks.
		h m	° ′		°	″				
h 4460	7·5	11 34	57 11	41	176·3	8·58	1·3	...	2	
Howe 17	6·9	11 49	37 12	16	277·7	2·05	...	...	1	
Washburn 115	8·3	11 59	57 11	44	244·8	1·84	1·5	...	2	
h 4498	5·9	12 1	65 9	44	61·6	8·75	...	3, B	2	
Jacob [8]	6·4	12 5	34 9	53	19·8	3·15	2·0	...	1	32
Lac. 5049	7·0	12 6	44 52	36	170·8	2·34	2·8	4, B	2	33
h 4507	8·1	12 8	44 20	45	223·4	16·3	...	4½, B	2	
Innes 81	9·0	12 10	29 13	36	344·0	2·71	...	...	1	34
λ 154	5·1	12 21	50 54	55	284·8	22·5	8·4	3, —	1	35
Innes 35	8·5	12 21	76 7	31	315·3	2·37	...	...	1	
Cape 12	7·0	12 23	61 12	39	260·1	2·09	0·8	4, 2	2	
Lac. [5169]	6·2	12 23	55 51	55	290·5	49·2	5·8	4, —	1	
Innes 36	7·7	12 23	61 19	40	325·3	21·8	4·8	...	2	
„ 218	7·3	12 24	37 25	28	234·5	2·34	2·5	3, *b*	2	
„ 309	7·7	12 26	77 39	31	nil	...	...	...	1	
„ 82	7·9	12 26	40 57	28	353·7	0·80	1·0	...	2	3
„ 219	8·5	12 26	55 34	26	50·0	1·64	1·0	...	2	3
„ 296	6·7	12 33	74 49	42	274·3	1·84	2·3	2, *b*	2	3
γ Centauri A−B	2·4	12 36	48 25	36	355·7	1·54	...	...	2	
„ AB−C				36	117·5	39·5	11·6	...	2	4
Innes 324	8·5	12 37	83 7	33	279·2	3·89	0·8	...	2	
h 4544	9·0	12 39	78 55	44	298·8	3·05	2·5	3, B	2	
β Muscæ	3·3	12 40	67 37	39	344·5	1·16	0·1	3, 3	2	
β Crucis	1·7	12 42	59 8	43	322·3	44·4	...	...	2	
ι Octantis	6·3	12 44	84 35	55	nil	...	...	...	1	
Lac. 5299	6·7	12 47	53 17	55	211·8	7·01	4·0	4, *b*	1	
Innes 83	7·0	12 51	47 9	37	277·2	0·54	0·1	3, 3	2	
„ 363	8·5	12 55	67 19	33	194·2	2·62	1·3	...	2	
C.Z. 12h 3298	8·5	12 57	59 4	44	356·0	3·56	0·1	...	2	
λ 168	7·5	12 58	38 26	35	nil	...	...	...	1	
Ref. Cat. 14 A−B	4·7	13 6	59 23	53	345·5	1·55	3·2	...	2	
C.P.D. 6088	8·3	13 7	40 13	44	236·2	2·26	0·5	...	2	
Lac. 5456	6·8	13 11	67 58	50	214·0	0·47	0·7	1, 1	4	
C.Z. 13h 629	8·7	13 12	40 1	53	320·3	1·05	1·5	0, 0	2	
Innes 220	7·7	13 19	34 7	44	6·6	0·63	1·5	3, 3	2	
Cape 32	8·4	13 20	52 46	53	263·1	4·08	1·0	...	1	

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Innes 298	7·2	13 25	68 43	36	205·3	0·75	1·7	4, 4	2	
„ 365	6·5	13 30	61 11	46	214·3	0·39	0·2	3·3, 3·3	3	46
„ 221	7·2	13 31	31 54	54	167·7	0·56	1·5	...	2	
λ 183	8·0	13 32	31 51	53	Looks single		...	...	1	
Innes 401	8·5	13 49	42 5	29	232·0	0·41	0·1	3, 3	2—1	
„ 225	7·2	13 54	62 28	26	299·8	...	...	...	1	
„ 325 A—C	8·7	14 11	68 10	55	43·9	44·8	...	...	1	47
„ „ B—C				55	222·5	7·98	...	...	1	
Russell 244	6·5	14 16	47 52	40	123·4	4·01	2·8	3, B	2	48
Y 6052	7·3	14 19	27 41	54	282·7	0·60	1·2	4½, 4½	2	
τ_2 Lupi	4·4	14 20	44 56	55	176·7	0·30	...	...	3	49
Cordoba (35)	8·2	14 21	23 46	54	133·6	2·31	1·3	2, *b*	2	
P. 14h 87	5·6	14 24	44 52	58	309·9	10·4	4·4	...	1	50
β 1112	6·0	14 27	30 16	56	6 0	2·36	3·0	4, *b*	2	
Lac. 5985	7·0	14 27	32 53	54	158·7	14·2	4·0	4, B	2	41
λ 4685	9·0	14 28	45 43	37	80·0	2·40	0·8	—, *b*	2	22
λ 4687	7·7	14 29	36 6	57	91·2	1·54	0·1	...	2	51
α Lupi	5·4	14 31	45 42	50	25·2	19·2	...	4·2, B	2	
α Centauri	0·2	14 33	60 25	11	211·1	...	...	...	1	87
				13	211·2	21·63	...	...	4	88
				31	211·3	21·66	...	3, 2	5	89
Innes 236	5·6	14 43	72 47	52	101·6	1·82	2·0	3½, *b*	2	
λ 4707	7·7	14 46	66 0	53	118·6	0·58	0·3	3, 3	1	
Innes 226	7·0	14 48	33 44	41	218·4	2·55	4·2	...	2	52
G.P.Z. 10498	8·8	14 49	70 32	52	347·3	2·03	1·6	...	2	53
Innes 328	9·0	14 49	84 46	52	175·6	2·11	0·8	...	2	
„ 227	7·3	14 50	34 14	41	89·8	0·40	0·3	3, 3	2	
„ 85	8·5	14 59	35 32	55	182·8	0·80	0·9	...	2	
C.Z. 14h 3790	8·3	15 1	42 43	51	182·3	1·89	0·2	2, 2	2	54
λ Lupi	4·3	15 2	44 54	56	193·4	0·61	0·3	2, 2	2	
Innes 238	8·2	15 5	44 38	45	140·4	2·93	2·7	...	2	55
Lac. 6259	6·3	15 9	60 34	31	317·6	10·7	...	...	1	56
λ 4750	7·3	15 9	47 40	38	19·9	13·3	3·0	...	1	
C.P.D. 5889	8·2	15 10	60 0	52	341·6	3·29	0·8	0, 0	3	57
Innes 370	5·4	15 11	60 8	52	116·8	5·07	7·6	2, —	3	
„ 332	6·6	15 12	67 7	53	107·2	1·21	2·0	3, —	1	
β Lupi	4·2	15 12	47 30	45	155·1	1·50	0·0	3, 3	2	

Star.	Mag.	1900. R.A.	1900. S. Dec.	1902·±	Pos. Angle.	Dist.	Diff. of Mags.	Colours A,B.	No. of Nights.	
		h m	° ′		°	″				
Innes 371	... 8·9	15 14	58 30	53	292·3	0·78	1·0	...	1	
Sellors 20	... 8·5	15 16	47 33	50	215·2	1·15	0·4	3, 3	3	5
Innes 87	... 9·2	15 19	38 24	31	245·2	1·20	0·2	3, 3	1	5
„ 239	... 7·0	15 23	31 8	32	356·4	0·48	0·4	0, 0	2	
„ 240	... 7·2	15 27	64 47	33	189·1	2·40	3·0	4, B	4	6
„ 241	... 8·0	15 28	64 12	36	19·1	9·94	4·0	...	1	6
γ Lupi	... 3·0	15 28	40 50	32	88·0	0·68	...	...	2	
Innes 89	... 6·8	15 34	39 39	33	148·6	1·31	1·0	...	1	
½ Normæ	... 4·8	15 55	57 30	51	231·8	0·52	...	3, 3	1	6
λ 259	... 7·1	15 56	36 28	51	single	...	...	...	1	
Cordoba (43)	8·0	15 56	37 46	35	140·4	4·75	0·3	...	2	
A 4828	... 8·5	15 58	43 4	48	92·2	8·27	...	...	1	
Harvard	... 6·4	15 58	37 35	33	146·3	40·0	6·6	...	1	
Ref. Cat. 16^h 6					Is same as No. 5			...	...	
λ 266 ...	... 7·2	16 3	35 23	51	single	...	...	...	1	
δ Tri. Aust.	... 4·0	16 6	63 26	51	„	...	...	...	1	6
λ 269 ...	... 6·8	16 10	52 50	51	„	...	...	...	1	
Innes 15	... 7·0	16 11	64 24	40	315·2	1·01	2·5	...	2	2
λ Normæ	... 5·6	16 12	42 26	51	162·5	0·42	1·0	2, 2	1	6
λ 272 ...	... 6·7	16 13	35 15	51	278·0	0·40	0·0	4, 4	1	
Ref. Cat. 16^{h}26	7·3	16 13	39 15	51	single	...	...	...	1	
λ 273 ...	... 7·5	16 13	39 23	51	„	...	...	...	1	
Innes 91	... 6·3	16 14	39 11	50	295·4	10·7	2·9	...	2	
„ 93	... 7·7	16 19	47 49	51	287·6	0·95	2·5	...	1	6
„ 94	... 7·7	16 20	29 42	51	205·8	0·68	1·5	4, —	1	
„ 404	... 9·1	16 27	52 27	42	122·0	4·18	0·5	...	2	
Harvard	... 6·8	16 29	72 6	51	245·7	2·05	3·5	4, B	1	3
Innes 405	... 8·9	16 32	46 27	51	318·0	2·60	0·0	0, 0	1	
„ 97	... 8·5	16 34	48 34	43	single	...	...	...	2	
Lac. 6968	... 7·7	16 40	45 17	44	359·4	0·57	0·6	...	2	
Innes 100	... 6·8	16 48	73 16	48	180·5	0·66	2·0	...	2	
„ 101	... 9·0	16 48	40 54	36	354·9	1·42	...	...	1	
λ 316 ...	... 6·4	16 53	48 30	48	185·6	0·63	1·0	5, 5	2	
Cordoba (48)	7·0	16 55	50 1	51	234·6	8·00	...	...	1	
Innes 406	... 8·7	17 1	41 49	41	96·2	1·90	0·0	...	2	
„ 407	... 7·1	17 1	41 29	41	186·2	0·76	0·6	2, 2	2	
„ 246	... 7·5	17 4	27 39	49	33·5	1·29	3·2	2,—	3	
Cape 34	... 8·7	17 5	41 52	56	33·1	7·39	3·7	...	2	

Star.	Mag.	1900. R.A. h m	1900. S. Dec: ° ′	1902·±	Pos. Angle. °	Dist. ″	Diff. of Mags.	Colours A.B.	No. of Nights.	Remarks.
λ 4926 A–B	7·0	17 8	39 39	60	335·2	14·3	...	...	1	68
A–C				60	209·8	17·1	3·0	...	1	
Innes 229	... 8·5	17 8	39 32	53	237·4	4·44	...	6, B	2	
„ 104	... 6·5	17 9	69 56	51	132·9	2·10	...	3, B	1	
„ 408	... 7·1	17 9	42 14	38	167·9	1·83	2·0	3, *b*	2	
λ 322	... ... 6·9	17 9	33 37	40	351·7	...	...	...	1	69
Brisbane	... 5·5	17 11	46 32	38	79·2	2·21	3·5	4, B	2	
β 416 = Mel.(4)	5·9	17 12	34 53	36	292·1	2·29	1·2	5, 5	3	
A–C				36	131·0	29·6	...	...	2	
C–D				33	48·7	35·5	D, 13^m	...	1	70
Innes 409	... 8·8	17 12	39 40	33	37·2	5·12	2·0	...	1	
„ 410	... 8·3	17 14	42 33	40	285·0	2·81	1·7	3, *b*	2	71
„ 385 A–B	7·5	17 16	59 7	51	167·7	0·44	1·5	...	1	72
AB–C				51	210·2	17·0	...	...	1	
7 Aræ	... ... 3·4	17 17	56 17	60	329·0	18·1	7·1	...	1	73
λ 4949	... ... 5·3	17 19	45 45	43	262·1	2·61	1·0	2, 2	2	
Cape 29	... 8·9	17 23	42 59	46	340·2	4·44	...	...	1	
Washburn 136	7·3	17 25	40 58	46	109·7	0·95	...	...	1	
Innes 247	... 7·1	17 31	37 48	43	112·9	1·23	2·5	3, *b*	3	
„ 107	... 8·9	17 33	32 18	33	137·9	1·60	0·3	...	1	
Lac. 7370	... 6·9	17 35	56 58	40	108·9	1·14	2·0	...	1	74, 14
„ 7387	... 6·8	17 38	59 57	40	...	...	...	...	1	75, 14
Cape 24	... 8·6	17 41	45 0	48	330·0	3·94	...	...	2	
λ 4978	... 5·8	17 42	53 35	60	268·9	12·0	3·0	2, *b*	1	
λ 4981	... 9·0	17 42	50 15	57	17·9	2·25	0·2	0, 0	2	76
Innes 110	... 7·5	17 52	47 46	37	126·6	1·54	2·0	3, B	2	77
Harvard	... 5·6	17 57	75 54	40	231·0	25·9	7·4	5, —	1	78
Lac. 7604	... 7·7	18 7	50 20	51	144·9	0·34	0·4	2, 2	1	79
λ 5033	... 6·9	18 8	48 53	46	116·0	17·6	...	...	1	80
ξ Pavonis	... 4·2	18 14	61 32	51	150·1	3·28	4·0	6, *b*	1	
Cordoba [51]	7·9	18 16	42 49	46	138·3	3·33	...	...	1	
C.Z. XVIII. 1250	... 8·7	18 22	46 22	51	39·8	1·76	0·0	...	1	81
ν Telescopii	5·1	18 24	45 59	51	single	...	...	...	1	
Hargrave(317)	7·1	18 56	45 51	55	284·2	1·45	...	...	1	82
ζ Sagittarii	... 2·7	18 56	30 1	55	51·7	0·43	...	2, 2	1	
λ 403 A–B	7·2	19 57	36 20	55	single	...	...	...	1	83

Star.	Mag.	R.A. 1900. h m	S. Dec. ° ′	1902·±	Pos. Angle. °	Dist. ″	Diff. of Magn.	Colours A.B.	No. of Nights.	Remarks.
h 5168 ...	... 7·0	20 1	30 1	55	79·9	18·8	3·0	5, —	1	
C.P.D. 9113 ...	8·5	20 16	35 59	53	133·0	2·82	2·0	...	2	84
Russell 321 ...	6·7	20 20	37 44	53	83·4	1·31	2·2	3, *b*	2	85
Innes 379 A–B	5·9	20 59	73 34	46	...	...	...	...	2	86
„ AB–C				51	134·4	8·40	8·1	...	1	
„ 258	... 7·7	21 5	60 27	55	110·5	0·52	1·2	...	2	
„ 19	... 7·0	21 41	65 58	51	339·8	1·24	1·2	...	1	
„ 381	... 8·2	21 59	56 57	55	111·0	1·85	1·5	...	2	
„ 20	... 6·8	22 11	63 19	51	339·3	0·55	0·6	...	1	
Cordoba (63) ...	6·5	22 37	47 43	58	132·2	7·70	...	...	1	

Remarks.

No.

1. B is purplish.
2. Epoch, 1901·01, omitted last year by error.
3. Found on a triple chart plate and estimated as follows:—1898, 280° ±, 16″ ± comp. about 11ᵐ. Also seen in the 18-in.; but the comp. was too faint to measure. The an. prop. mot. of the chief star is 0″·092 towards 150°·8. Innes 412.
4. Found in 1896 by Mr. W. H. Cox at the T. Circle. Cape 38.
5. Innes 413. Found with the 7-in. About 25′ S.f. *β* 311.
6. Innes 414. This close pair was found with the 7-in. and confirmed with the 18-in. The p.m. is under 0″·01.
7. Cape 39. Found by Mr. Cox at the Transit-Circle.
8. Not too sure.
9. Colours very fine.
10. Most difficult.
11. A 12ᵐ·5 star at 320° ±, 18″ ±, several other faint stars near.
12. No third comp. seen.
13. Wrongly identified in Ref. Cat.; is C.Z. 8ʰ, 2233.
14. The prop. mot. is very small.
15. P. M. = *α* + 0ˢ·001, *δ* − 0″·01.
16. Always most difficult, distance decreasing. Recent measures are:—

1897·1	256°·1	0″·56	See and Cogshall.
1899·3	275·0	0·72	Aitken.
1900·3	292·8	0·76	Cape.
1901·2	307·2	0·70	„
1902·2	338·8	0·48	„

17. New = Cape 40. Found by Mr. J. Power at the T. C. A 13ᵐ·5 star 230° ±, 9″ ± from A; is 5″ ± from B. The mag. of A is from the C.P.D., the Cor. DM. has 9ᵐ·5. My estimate was 8ᵐ·3.
18. Smaller component precedes. In 1901·09 I found this star to be single.
19. The star measured for Innes 290 on 1901·09 is C.P.D. − 59°, 171 C.P.D. − 59°, 1699 and 1718 = Innes 415 and 416 were measured by accident for Innes 290. In a cluster containing many small pairs.
20. Distance on 1900·22:—for 35″·1 read 26″·1, error of reduction.
21. Transit-Circle double star = Cape 41.
22. Colours slightly contrasted.

Another *comes* at 20″·(not 20′, as in Ref. Cat.).
Epoch 1901·18, omitted in 1901 list. Angle decreasing?
Another *comes* 13½ mag., 235°±, 15″±.
A−B added with the 18-in. = Innes 417.
New = Innes 418. Found with the 7-in. There is a faint wide pair N. f. The prop. mot. is uncertain, as the observations available are discordant.
New = Innes 419. Found with the 7-in. This pair is in the magnificent cluster around *x Carinæ*, and is not fainter than 8ᵐ·5; but C.G.A. gives 9¼ᵐ, C.P.D. 9ᵐ·2. It is No. 483 of Gould's Cordoba Photographs of the cluster, but it is not identified; mag. there = 9·5.
A 14ᵐ star, 10°±, 28″±.
Picked up with the 18-in = Innes 420. It is the following of two stars near the variable R. S. Centauri.
New = Innes 421. Found with the 7-in. Many faint stars within 40″.
New quadruple star = Innes 422. C was found with the 7-in. The chief star was found to be double, and D added with the 18-in. The angles for A−B are discordant, viz. 89°·1, 101°·7, and 91°·5.
Both components singie.
New = Innes 423. Found with the 7-in. The prop. mot. is very small.
In 1901 angle to read 344°·0 and not 334ᶜ·0, as printed.
The prop. mot. is 0″·083 towards 232°·9.
λ 89. No compn. seen. Is perhaps a misidentification of the star Ref. Cat. 7ʰ No. 71.
P.m. = 0″·09 towards 263°·7.
The companion was not seen here in 1901.
P.m. = 0″·21 towards 349°·3.
Poor measures, as the faint star was difficult to see. See has 29″·8, which would seem to be too small by 10″.
Found by Prof. Bailey at Arequipa and kindly communicated by Prof. E. C. Pickering.
Prop. mot. = 0″·10 towards 270°. This star is called "double" in Brisbane, but unless there has been much change the present companion could not have been seen at Parramatta.
Added with the 18-in. = Innes 424. λ 170, See's comp. at 0″·34 was not seen, but the chief star had perhaps a very doubtful elongation towards 130°. Professor See did not observe the new *comes*; but it is a difficult object, on account of the disparity of magnitude, and could be very easily overlooked, as indeed it was by myself in 1901 when measuring the distant star noted at Arequipa in 1891.
Transit-Circle pair = Cape 42.
New = Innes 425. Found with the 18-in.
Prop. mot. = 0″·19 towards 145°·7. Change of position-angle = 19° in two years.
A 13th mag. star about midway between A and C.
Prop. mot. = 0″·04 towards 257°·2.
,, = 0″·04 ,, 244°·0.
,, = 0″·077 ,, 270°·0. Found with the 18-in. = Innes 426.
Angle increasing slowly; distance decreasing.
The *comes* was not seen in 1901. A fainter star 30″ in same direction.
New = Innes 427, found with the 18-in.
New = Cape 43. Found at the Transit-Circle. Mag. from C.P.D. Cor. 10M. has 9ᵐ·0, which is too faint. A 12ᵐ star is S.f. Prop. motion of the chief star = 0″·06 towards 190°·0.
Prop. mot. = 0″·03 towards 288°·0. There is an 11ᵐ·5, 310°±, 20″±.
This was also measured in 1901 for δ Circini. The Arequipa *comes* to the latter star was estimated 12ᵐ, 270°±. 50″±, when the former was measured. Lac. 6259 = Innes 428.

No.

57. Found by Mr. W. H. Cox at the T.-C. = Cape 44.
58. Large common prop. mot. of 0″·47, but relatively fixed.
59. This star has been elsewhere misidentified and measured as λ 236.
60. Perhaps the chief star is elongated towards 232°.
61. This is the only near companion.
62. Is λ 258. This fine pair has decreased in angle 35° since 1897.
63. The Arequipa *comes* 20″ S.f. seen. I would suggest that the estimate of 1880 has been misprinted, and should read 140° ±, 30″ ±.
64. Is λ 271, in 1897 angle = 152°. P.m. = 0″·03 towards 225°.
65. Com. prop. mot. of 0″·09 towards 257°·5.
66. Distance in 1900 to read 1″·35. Colours slightly contrasted.
67. P.m. = α − 0·004 sec., δ − 0″·10.
68. The changes indicated by Prof. See's measures in 1896 are not confirmed. For A − B the micrometer was set to 331°·8 (Prof. See's angle), but the disagreement was very evident. Prof. See also measured the chief star as a double (0″·6) on two nights. It is now certainly single.
69. Elongation doubtful, still the star does not look single. The measures were fairly accordant (1897, 361°·3, 0″·2, See, 1*n*).
70. The *comes* D was added in 1897 by Professor See. Transferring the Cape measure to A we have for comparison :—

A − D,	1897·4	86°·1	55″·4	See.	1*n*.
„	1902·3	84·4	49·8	Innes.	1*n*.

This change is exactly accounted for by the proper motion of the triple system A − B − C ; hence D is not connected with the system.

71. Prop. mot. = α + 0ˢ·001, δ − 0″·09.
72. It is unfortunate that only one night's obs. of this system could be procured both in 1900 and 1902. We have :

1900·72	184°·3	0″·51
1902·51	167·7	0·44

73. A 12½-mag. *comes* at twice the distance.
74. Found by Mr. Clymer at Arequipa and kindly communicated by Prof. E. C. Pickering.
75. Suspected by Mr. Clymer. If double, certainly under 0″·4 if components are sensibly equal in mag. the star looks single.
76. This star is C.Z. xvii., 2739. Lac. 7437, mag. 7·5, is 46 secs. f.
77. Prop. mot. = α − 0ˢ·008, δ − 0″·03.
78. „ „ = 0″·26 towards 184°·0.
79. Found with the 7-in. = Innes 429. Prop. mot. = 0″·09 towards 257°·5.
80. This pair, with two other stars, form an isolated rhomboid. There is no material for the determination of proper motion, but it cannot be large.
81. Found at the Transit-Circle = Cape 45.
82. Prop. mot. = 0″·04 towards 194°·0, in which the *h* companion probably shares.
83. This pair is under 0″·4 if double. Prof. See's third component was also invisible. There is a 13th-mag. star 15″ N. pr. not noticed by Prof. See.
84. Found in 1897 = Innes 430. There is a 9ᵐ star 4ˢᵉᶜˢ. pr., 1′·3 S. Lac. 8406, mag. 68 is 1ᵐ·ᵃ· pr.

h.

85. This fine pair has a com. prop. mot. of 0″·341 towards 245°·8. The measures are:—

	°	″		
1880·9	97·0	1·07	Russell.	1*n*.
1890·7	96·0	1·08	Sellors.	1
1896·7	99·7	0·78	See.	3
1902·5	83·4	1·31	Innes.	2

On the occasion of the last measure the wire was purposely set at 99°, but it was impossible; query if in 1896, a misprint for 89°.

86. The close pair was estimated 318° and 240° on two occasions. Probably single at present.

87. Day. By Sir D. Gill.

88. Day.

89. Right.

Cometary Observations at the Liverpool Observatory. By W. E. Plummer, M.A

Observations of Comet b 1902 (Perrine).

Greenwich Mean Time of Observation.				♂ − ✱ Ret.	No. of Comp.	Apparent R.A. of ♂.	♂ − ✱ Decl.	No. Comp.	App. Decl. of ♂.	Log. Factor of Parallax a.	Log. Factor of Parallax b.	Star of Comp.
		h	m	s	m s	h m s	′ °		° ′ ″			
Sept.	3	10	22	50·4	−2 19·45	35	3 15 36·34	− 3 0·3	5	+35 37 15·2	−9·6345	0·7635	*a*
		10	22	50·4	−3 35·69	25	3 15 36·40	− 3 1·7	5	+35 37 15·9	−9·6345	0·7635	*b*
	4	10	27	46·0	−2 40·61	16	3 14 29·42	+ 3 27·7	5	+36 3 19·7	−9·6369	0·7615	*c*
	5	10	2	35·1	− 0·49	20	3 13 15·95	− 1 4·4	5	+36 30 8·0	−9·6370	0·7774	*d*
		10	2	35·1	+1 14·02	20	3 13 15·89	+ 1 47·2	5	+36 30 8·8	−9·6370	0·7774	*e*
	6	10	40	26·0	+2 47·41	16	3 11 50·32	+ 5 9·5	4	+36 59 26·9	−9·6412	0·7315	*f*
	8	10	2	16·9	−2 5·10	20	3 8 37·26	− 1 46·4	5	+37 59 57·8	−9·6477	0·7551	*g*
	18	10	4	31·2	+ 3·45	15	2 35 28·36	+ 1 25·2	6	+45 6 1·1	−9·6787	0·5948	*h*
	19	10	29	24·8	−2 29·10	16	2 29 22·18	− 4 10·9	5	+46 3 53·4	−9·6614	0·5173	*i*
	23	8	18	16·0	−2 41·71	16	1 56 28·92	+ 3 26·2	5	+50 14 1·2	−9·7388	0·6558	*j*
	24	8	2	0·3	+ 3·90	15	1 44 49·89	− 4 34·3	4	+51 22 43·3	−9·7485	0·6136	*k*
	25	7	47	10·9	+ 1·86	15	1 31 20·92	− 1 42·2	6	+52 31 55·2	−9·7592	0·5962	*l*
	26	7	30	30·1	−2 4·68	16	1 15 46·55	− 4 16·9	6	+53 39 46·7	−9·7677	0·5394	*m*
	28	9	3	20·1	− 6·79	16	0 34 55·64	−14 16·7	5	+55 46 2·9	−9·6530	9·9772	*n*
Oct.	1	7	25	45·7	+2 43·07	10	23 15 18·99	− 6 39·9	3	+57 0 38·0	−9·6893	9·9654	*o*
	2	7	31	16·3	+1 52·99	15	22 43 21·66	− 3 46·8	5	+56 34 14·9	−9·5900	9·6037	*p*
	5	7	14	11·2	+5 3·24	12	21 8 49·92	+ 4 43·7	4	+51 41 55·9	−9·1762	9·5806	*q*
		7	14	11·2	+4 32·89	12	21 8 50 25	+ 2 12·3	4	+51 41 58·0	−9·1762	9·5806	*r*
	8	7	26	10·4	+ 27·43	16	19 54 30·45	− 20·8	5	+42 22 22·9	+8·8893	0·2304	*s*

Mean Places of Stars & Comparison

Star's Designation or Authority.	Mean R.A. 1902·0.	Corr. to Apparent Equinox.	Mean Decl. 1902·0.	Corr. to Apparent Equinox.	Letter of Reference.
	h m s	s	° ′ ″	″	
A. G. C. (Lund) No. 1747	3 17 51·81	+3·98	+35 40 14·6	+ 0·9	*a*
„ „ No. 1762	3 19 8·12	+3·97	+35 40 16·8	+ 0·8	*b*
„ „ No. 1744	3 17 5·98	+4·05	+35 59 50·4	+ 1·6	*c*
„ „ No. 1712	3 13 12·34	+4·10	+36 31 11·0	+ 1·4	*d*
„ „ No. 1700	3 11 57·77	+4·10	+36 28 20·2	+ 1·4	*e*
„ „ No. 1673	3 8 58·75	+4·16	+36 54 15·6	+ 1·8	*f*
„ „ No. 1688	3 10 38·09	+4·27	+38 1 42·6	+ 1·6	*g*
A. G. C. (Bonn) No. 2271	2 35 19·83	+5·08	+45 4 30·7	+ 5·2	*h*
„ „ No. 2219	2 31 46·08	+5·20	+46 7 58·6	+ 5·7	*i*
„ „ No. 1769	1 59 5·19	+5·44	+50 10 27·5	+ 7·5	*j*
A. G. C. (Cambridge, Mass.) No. 846	1 44 40·23	+5·76	+51 27 6·3	+11·3	*k*
„ „ „ No. 722	1 31 13·20	+5·86	+52 33 24·4	+13·0	*l*
„ „ „ No. 618	1 17 45·24	+5·95	+53 43 48·9	+14·7	*m*
α Cassiopeiæ	0 34 56·44	+5·99	+55 59 59·6	+20·0	*n*
A. G. C. (Helsingfors) No. 13903	23 12 30·60	+5·32	+57 6 48·9	+29·0	*o*
„ „ „ No. 13398	22 41 23·80	+4·87	+56 37 30·1	+31·6	*p*
A. G. C. (Cambridge, Mass.) No. 6906	21 3 43·39	+3·29	+51 36 36·5	+35·7	*q*
„ „ „ No. 6908	21 4 14·06	+3·30	+51 39 10·0	+35·7	*r*
A. G. C. (Bonn) No. 13585	19 54 0·61	+2·41	+42 22 28·3	+33·8	*s*
Leiden Zones, 65 No. 70	19 6 27·62	+2·10	+31 53 8·0	+29·4	*t*

On Jacobi's Method of Facilitating the Numerical Solution of Equations arising in the Theory of Secular Perturbations.

By H. C. Plummer, M.A.

1. The equations to be considered here are of the type

$$\Delta = 0$$

where Δ is a symmetric determinant which may be written in the form

$$\begin{vmatrix} A_{11}-\lambda, & A_{12}, & \dots & A_{1n} \\ A_{21}, & A_{22}-\lambda, & \dots & A_{2n} \\ \dots & \dots & \dots & \dots \\ A_{n1}, & A_{n2}, & \dots & A_{nn}-\lambda \end{vmatrix}$$

and which is no other than the familiar discriminating determinant which occurs in so many branches of mathematics. As it arises in the determination of the mean motions of the perihelion and the node, the number of rows and columns corresponds to the number of the planets. In the application to the solar system the determinant is of the eighth order; and little reflexion is necessary to see that its direct reduction would entail enormous labour. Hence Jacobi's method* of approximating to the numerical values of the roots without reducing the determinant is of great practical interest.

2. The principle of Jacobi's method may be briefly recalled. The vanishing of Δ is the condition of the consistency of the system of n linear equations

$$(A_{11}-\lambda)x_1 + A_{12}x_2 + \dots + A_{1n}x_n = 0$$
$$\dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots$$
$$A_{n1}x_1 + A_{n2}x_2 + \dots + (A_{nn}-\lambda)x_n = 0$$

where $A_{rs} = A_{sr}$. Let $[i]$ and $[k]$ denote the ith and kth equations. The substitution

$$x_i = \chi_i \cos\alpha - \chi_k \sin\alpha$$
$$x_k = \chi_i \sin\alpha + \chi_k \cos\alpha$$

is made and $[i]$ and $[k]$ are replaced by $[i]\cos\alpha + [k]\sin\alpha$ and $-[i]\sin\alpha + [k]\cos\alpha$. Then if

$$\cot 2\alpha = (A_{kk} - A_{ii})/2A_{ik}$$

the eliminant of the equations thus transformed is a symmetric determinant of exactly the same *form* as before. If A'_{rs} be the constituent corresponding to A_{rs} in the transformed determinant, we have

* 'Über ein leichtes Verfahren die in der Theorie der Säcularstörungen vorkommenden Gleichungen numerisch aufzulösen,' *Werke*, vol. vii. p. 111; Crelle, vol. xxx. (1846), p. 64.

$$A'_{ik} = A'_{ki} = 0$$
$$A'_{ii}{}^2 + A'_{ik}{}^2 = A_{ii}{}^2 + A_{kk}{}^2 + 2A_{ik}{}^2$$
$$A'_{ij}{}^2 + A'_{kj}{}^2 = A_{ij}{}^2 + A_{kj}{}^2,\ j \neq i \neq k.$$

result of the transformation is therefore to annihilate two l constituents and to leave unaltered the sum of the squares he other constituents outside the leading diagonal. The ss can be repeated until the sum of the squares of the con- ents becomes very small except in the leading diagonal, the tituents in which approximate to the factors of the determi- , and will accordingly give the roots of the equation. The oximations to the roots after a certain number of transforma- can be completed by a different process, also due to Jacobi. . It may be interesting to study the theory underlying this od in a more general manner. For this purpose let the rminant Δ be multiplied by

$$\delta = \begin{vmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{vmatrix}$$

mode of composition being by rows of each determinant in a way that rows of Δ appear in the corresponding rows of The constituent in the jth row and sth column of the product

$$= \sum_{i=1}^{i=n} A_{ji}\, a_{si} - \lambda a_{sj}$$

t let the determinant $\delta\Delta$ be multiplied by δ, the mode of position being by columns of $\delta\Delta$ and rows of δ. The con- ent in the r^{th} row and s^{th} column of the final product

$$= \sum_{j=1}^{j=n} a_{rj} \left[\sum_{i=1}^{i=n} A_{ji}\, a_{si} - \lambda .\ a_{sj} \right]$$
$$= \sum_{i=1}^{i=n} \sum_{j=1}^{j=n} A_{ji}\, a_{si}\, a_{rj} - \lambda . \sum_{j=1}^{j=n} a_{rj}\, a_{sj}.$$

s expression is unaltered by the interchange of r and s, and refore the resulting determinant is symmetrical.

4. The determinant $\delta^2\Delta$ is not only symmetrical but is also of ctly the same form as Δ, provided that

$$\sum_{j=1}^{j=n} a_{rj}{}^2 = 1,\ (r = 1, 2, \dots, n)$$
$$\sum_{j=1}^{j=n} a_{rj}\, a_{sj} = 0,\ (r, s = 1, 2, \dots, n\ ;\ r \neq s)$$

at is, provided that δ is the modulus of an orthogonal trans- mation scheme

$$x_1 = a_{11}\, y_1 + a_{21}\, y_2 + \dots + a_{n1}\, y_n$$
$$\dots\dots$$
$$x_n = a_{1n}\, y_1 + a_{2n}\, y_2 + \dots + a_{nn}\, y_n$$

which is such that

$$x_1^2+x_2^2+\ldots+x_n^2 \equiv y_1^2+y_2^2+\ldots+y_n^2$$

If these conditions are fulfilled, with their well-known consequences, and if

$$\sum_{i=1}^{i=n}\sum_{j=1}^{j=n} A_{ji}\, a_{si}\, a_{rj} = B_{rs}$$

then $\delta^2\Delta =$

$$\begin{vmatrix} B_{11}-\lambda, & B_{12}, & \ldots & B_{1n} \\ B_{21}, & B_{22}-\lambda, & \ldots & B_{2n} \\ \text{—} & \text{—} & \ldots & \text{—} \\ B_{n1}, & B_{n2}, & \ldots & B_{nn}-\lambda \end{vmatrix}$$

is identically equal to Δ, for $\delta^2 = 1$.

5. A number of identities may be deduced from this result. The coefficient of $(-\lambda)^{n-1}$ in Δ is

$$A_{11}+A_{22}+\ \ldots\ +A_{nn} = \Sigma A_{rr}$$

Hence
$$\Sigma A_{rr} = \Sigma B_{rr}$$

Again the coefficient of $(-\lambda)^{n-2}$

$$= \Sigma(A_{rr}A_{ss}-A_{rs}^2)$$

Hence

$$[\Sigma A_{rr}]^2-2\Sigma(A_{rr}A_{ss}-A_{rs}^2)$$
$$=[\Sigma B_{rr}]^2-2\Sigma(B_{rr}B_{ss}-B_{rs}^2)$$

which gives

$$\Sigma A_{rr}^2+2\Sigma A_{rs}^2 = \Sigma B_{rr}^2+2\Sigma B_{rs}^2$$

That is to say, the sum of the squares of the constituents is the same in both determinants. Moreover, the sum of the squares of the constituents in the rth row or column of $\delta^2\Delta$ is

$$\Sigma_s B_{rs}^2 = \Sigma_s(\Sigma_j\Sigma_i A_{ji}a_{si}a_{rj})^2$$
$$= \Sigma_s\Sigma_j\Sigma_i\Sigma_k\Sigma_l A_{ji}A_{kl}a_{rj}a_{rk}a_{si}a_{sl}$$
$$= \Sigma_i\Sigma_j\Sigma_k A_{ji}A_{ki}a_{rj}a_{rk}$$

for $\Sigma_s a_{si}a_{sl} = 0$ unless $l = i$, in which case the sum is unity.

6. The conditions which the n^2 coefficients of an orthogonal transformation must satisfy are $\frac{1}{2}n(n+1)$ in number. They can be so chosen as to satisfy in addition the $\frac{1}{2}n(n-1)$ conditions.

$$B_{rs} = \sum_{i=1}^{i=n}\sum_{j=1}^{j=n} A_{ji}\, a_{si}a_{rj} = 0, (r, s = 1, 2, \ldots, n;\ r \neq s)$$

Then all the constituents outside the leading diagonal of $\delta^2\Delta$ vanish, and the roots of the equation in λ become B_{11}, B_{22}, . . . B_{nn}, where

$$B_{rr} = \sum_{i=1}^{i=n}\sum_{j=1}^{j=n} A_{ji}a_{ri}a_{r}$$

But the complete solution of the equation $\Delta = 0$ is required in order to find the coefficients of the substitution. The additional relations given above show that

$$A_{11}x_1^2 + A_{22}x_2^2 + \ldots + 2A_{12}x_1x_2 + \ldots \equiv B_{11}y_1^2 \ldots + B_{nn}y_n^2$$

i.e. the substitution is one which transforms the quadratic form into a sum of square terms. Hence

$$(A_{11}-\lambda)x_1^2 + (A_{22}-\lambda)x_2^2 + \ldots + 2A_{12}x_1x_2 + \ldots \equiv (B_{11}-\lambda)y_1^2 + \ldots + (B_{nn}-\lambda)y_n^2$$

If now $\lambda = B_{rr}$, y_r disappears, and therefore

$$x_1\left[(A_{11}-\lambda)\frac{\partial x_1}{\partial y_r} + A_{12}\frac{\partial x_2}{\partial y_r} + \ldots + A_{1n}\frac{\partial x_n}{\partial y_r}\right]$$
$$+x_2\left[A_{21}\frac{\partial x_1}{\partial y_r} + (A_{22}-\lambda)\frac{\partial x_2}{\partial y_r} + \ldots + A_{2n}\frac{\partial x_n}{\partial y_r}\right]$$
$$+ \ldots \equiv 0$$

Hence

$$(A_{11}-\lambda)a_{r1} + A_{12}a_{r2} + \ldots + A_{1n}a_{rn} = 0$$
$$A_{21}a_{r1} + (A_{22}-\lambda(a_{r2} + \ldots + A_{2n}a_{rn} = 0$$
$$\ldots\ldots\ldots\ldots\ldots$$

These lead again to the equation $\Delta = 0$. The successive substitution of the roots of the latter equation in λ in the set of linear equations will yield the n sets of n coefficients.

7. It is thus seen that the complete transformation requires a knowledge of the roots of the very equation whose solution is to be effected. But it is possible to use a partial transformation instead of a complete one. The set of quantities $x_1, \ldots, x_n$ can be divided into two sets $x_1, \ldots, x_m$ and $x_{m+1}, \ldots, x_n$ of which the former is transformed as before, while the latter remains unchanged. This means that the terms of $\Sigma\Sigma_{i\ j} A_{ji}x_ix_j$ which involve the first set only are transformed into a sum of squares, those involving the second set only are unchanged, and the product terms involving one quantity from each set retain their form with changed coefficients. The transformation as a whole, as well as in part, remains orthogonal, but the coefficients of the substitution are such that $a_{si} = 0$ $(s \neq i;\ s \text{ or } i > m)$ and $a_{ss} = 1$ $(s > m)$. Three cases must be considered separately, and these results are easily deduced from the formula of § 3 :

(1) If $r > m$, $s > m$, then

$$B_{rs} = A_{rs}$$

(2) If $r > m$, $s \not> m$, then

$$B_{rs} = \sum_{i=1}^{i=m} A_{ri}\, a_{si}$$

(3) If $r \not> m$, $s \not> m$, then

$$B_{rs} = \sum_{j=1}^{j=m} \sum_{i=1}^{i=n} A_{ji}a_{si}a_{rj}$$

8. It is now possible to choose the m^2 quantities $a_{si}(s \gtrless m, i \gtrless m)$ according to the method of § 6 so as to make the terms $B_{rs}(r \neq s)$ of § 7 (3) vanish. In this way all the constituents of the minor formed of the first m rows and columns of Δ outside the leading diagonal can be made to vanish. Since by interchange of rows and columns the constituents of the leading diagonal can be made to take any order, it is clear that any minor on the leading diagonal can be transformed in this way. If the minor is a determinant of the mth order, the solution of an equation of the mth degree is required for the transformation and $m(m-1)$ constituents can be made to vanish. To the transformed minor the results of §§ 3–6 apply. The complementary minor on the leading diagonal will remain unaltered. As regards the outstanding constituents it is easily deduced either from § 7 (2) or from the formula in § 5 that the sum of the squares of constituents lying in a line parallel to a row or column of the transformed minor remains unaltered. This is the generalisation of the fact on which the principle of Jacobi's method depends. The sum of the constant terms in the axis of the transformed minor is unchanged, while the sum of their squares is increased by the sum of the vanishing constituents. Outside this minor the sum of the squares of the constituents is left, line for line, unchanged. Hence repetition of the process must cause the axial terms to approximate to the factors of the determinant.

9. Jacobi's method amounts to the use of the case in which $m = 2$. The auxiliary angle α which is introduced in § 2 has of course a simple geometrical meaning. It is the angle between the coordinate axes and the axes of the conic

$$A_{ii}x^2 + 2A_{ik}xy + A_{kk}y^2 = 1$$

and its connexion with the substitution theory is obvious. In Jacobi's method it is always possible to remove the numerically greatest pair of constituents outside the diagonal at each transformation. Hence if S is the sum of the $n(n-1)$ squares after the first transformation the square of the greatest $> S/(n-2)(n+1)$, and each further transformation will reduce the sum of the squares faster than in the ratio

$$1 : 1 - \frac{2}{(n-2)(n+1)}$$

In the general case of m substitutions the $m(m-1)$ constituent to be removed cannot be chosen independently, and after a certain number of transformations it may be necessary to include terms previously reduced. Short of this event the ratio of decrease of the sum of the squares may be expected to be at least

$$1 : 1 - \frac{m(m-1)}{(n-m)(n+m-1)}$$

Doubtless Jacobi's case is the simplest, but it would be theoretically possible to make $m = 4$, a case involving the solution of a biquadratic and removing twelve constituents. The case of $m = 3$, depending on a cubic and removing 6 constituents, would seem to be quite practicable and useful at least in the earlier transformations. In any case, when the factors of any axial minor are known, all the constituents of that minor outside the axis can be removed. The necessary substitutions might probably be facilitated by the use of an arithmometer. But after the work of Harzer, who employed Jacobi's method, it is unlikely that an occasion for employing such processes will recur.

10. The principle of Jacobi's method contains implicitly a proof that the roots of a discriminating determinant are real. The proof supposes the method repeated an infinite number of times. The idea of a limit may be avoided by the foregoing theory. For this it is only necessary to notice that if the extra-diagonal terms of a minor of any order be removed as before explained, it is possible to extend the process to a minor of an order higher by unity. That is to say, the process can be extended successively from a minor of the second order, for which it is always possible, to the complete determinant. For let the extra-diagonal constituents of Δ be zero except in the first row and column. Then

$$\Delta = \left[1 - \frac{A_{12}^2}{(A_{11}-\lambda)(A_{22}-\lambda)} - \frac{A_{13}^2}{(A_{11}-\lambda)(A_{33}-\lambda)} - \ldots\right]\Pi$$

where Π is the product of the diagonal terms. In Δ put $\lambda = A_{rr}$. Then

$$\Delta = -A_{1r}^2 (A_{22}-A_{rr})(A_{33}-A_{rr}) \ldots (A_{nn}-A_{rr})$$

Suppose that $A_{22}, A_{33} \ldots$ are in increasing order of magnitude. If now λ is put equal to $-\infty, A_{22}, A_{33}, \ldots, A_{nn}, +\infty$ in turn, it is easily seen that the resulting values of Δ are of alternating sign, and therefore Δ has real roots situated between the values, assigned to λ. And if $A_{22}, A_{33}, \ldots$ are not all different, the roots are still real. For if, for example, $A_{22} = A_{33}$, the expanded form of Δ shows that A_{22} is a root, and the order of Δ can be depressed by writing $A_{22}-\lambda$ only once in the diagonal and $\sqrt{[A_{12}^2 + A_{13}^2]}$ in the corresponding places of the first row and column. Hence, generally, a determinant of the form considered has real roots, and its extra-diagonal constituents can all be removed by a real substitution. Thus by successive steps it is proved that the roots of any discriminating determinant are real. It is not difficult to see that a similar method could be applied to the more general case of Langrange's determinant.

University Observatory, Oxford:
1902 *December* 6.

Ephemeris for Physical Observation

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	
1903.	°	°	°	"	"	"	°	°	
Mar. 28	335·811	203·012	+0·928	34·08	0·07	31·88	5·40	246·36	+
30	335·752	203·463	0·956	34·17	0·08	31·96	5·67	246·36	
April 1	335·695	203·910	0·984	34·26	0·09	32·05	5·94	246·37	
3	335·640	204·354	1·012	34·36	0·10	32·14	6·20	246·37	
5	335·587	204·795	1·039	34·46	0·11	32·24	6·46	246·38	
7	335·535	205·230	1·065	34·57	0·12	32·35	6·72	246·39	
9	335·485	205·663	1·091	34·68	0·13	32·45	6·97	246·40	
11	335·436	206·091	1·116	34·80	0·14	32·56	7·22	246·40	
13	335·388	206·514	1·141	34·92	0·15	32·67	7·46	246·41	
15	335·343	206·934	1·165	35·04	0·16	32·79	7·70	246·42	
17	335·300	207·347	1·188	35·17	0·17	32·91	7·94	246·42	
19	335·258	207·757	1·211	35·30	0·18	33·03	8·17	246·43	
21	335·218	208·162	1·233	35·44	0·19	33·16	8·39	246·43	
23	335·180	208·560	1·254	35·58	0·20	33·30	8·61	246·44	
25	335·144	208·954	1·275	35·73	0·21	33·44	8·82	246·44	
27	335·109	209·341	1·295	35·89	0·22	33·58	9·03	246·45	
29	335·075	209·724	1·315	36·05	0·23	33·73	9·24	246·45	
May 1	335·043	210·098	1·335	36·22	0·24	33·88	9·43	246·46	
3	335·012	210·468	1·355	36·39	0·25	34·04	9·62	246·46	
5	334·982	210·830	1·375	36·56	0·26	34·20	9·80	246·47	
7	334·956	211·186	1·395	36·74	0·28	34·37	9·98	246·47	
9	334·931	211·535	1·415	36·92	0·29	34·54	10·15	246·48	
11	334·907	211·877	1·435	37·11	0·30	34·72	10·31	246·48	
13	334·883	212·211	1·454	37·30	0·31	34·90	10·46	246·49	
15	334·859	212·538	1·474	37·49	0·32	35·08	10·61	246·49	
17	334·837	212·858	1·493	37·69	0·33	35·27	10·75	246·50	
19	334·817	213·169	1·512	37·90	0·34	35·46	10·88	246·51	
21	334·798	213·472	1·531	38·11	0·35	35·66	11·00	246·52	
23	334·780	213·767	1·550	38·33	0·36	35·86	11·12	246·53	
25	334·764	214·052	1·569	38·55	0·37	36·06	11·22	246·55	
27	334·749	214·330	1·588	38·77	0·38	36·27	11·32	246·56	
29	334·735	214·597	1·606	39·00	0·39	36·48	11·41	246·58	
31	334·722	214·855	1·624	39·23	0·39	36·70	11·49	246·60	
June 2	334·710	215·103	1·641	39·47	0·40	36·92	11·55	246·62	
4	334·698	215·343	+1·659	39·71	0·40	37·15	11·61	246·64	+

Jupiter, 1903–4. By A. C. D. Crommelin.

Greenwich Mean.	Longitude of ♃'s Central Meridian. $877^{\circ}{\cdot}90$ I.	$870^{\circ}{\cdot}27$ II.	Corr. for Phase.	Light-time.	A − O.	B.
1902.	°	°	°	m	°	°
Dec. 28	296·07	299·67	+0·13	48·743		
30	251·49	239·84	·14	48·617		
1903. Jan. 1	206·93	180·01	·15	48·486	197·969	+0·950
3	162·37	120·19	·17	48·349		
5	117·82	60·38	·18	48·206		
7	73·27	0·57	·19	48·057		
9	28·73	300·77	·21	47·902		
11	344·20	240·98	·23	47·742	198·866	0·996
13	299·68	181·20	·24	47·578		
15	255·17	121·42	·26	47·409		
17	210·66	61·65	·28	47·233		
19	166·16	1·89	·29	47·053		
21	121·67	302·14	·31	46·868	199·763	1·041
23	77·19	242·40	·32	46·678		
25	32·71	182·66	·34	46·483		
27	348·24	122·93	·35	46·283		
29	303·78	63·21	·37	46·079		
May 1	259·33	3·50	·39	45·871	200·662	1·087
3	214·89	303·80	·40	45·658		
5	170·46	244·11	·42	45·441		
7	126·04	184·43	·43	45·222		
9	81·63	124·76	·45	44·997		
11	37·23	65·10	·46	44·771	201·561	1·132
13	352·84	5·44	·48	44·541		
15	308·45	305·79	·49	44·307		
17	264·07	246·15	·50	44·070		
19	219·71	186·52	·52	43·831		
21	175·36	126·90	·53	43·590	202·462	1·176
23	131·02	67·29	·55	43·345		
25	86·68	7·70	·56	43·098		
27	42·35	308·12	·56	42·848		
29	358·04	248·54	·57	42·597		
31	313·73	188·97	·57	42·345	203·363	+1·221
June 2	269·43	129·41	·58	42·091		
4	225·15	69·87	+0·59	41·836		

Greenwich Noon.	P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1903.	°	°	°	″	″	″	°	°	°
June 6	334·687	215·571	+1·676	39·95	0·41	37·38	11·66	246·66	+1·79
8	334·677	215·790	1·693	40·20	0·41	37·61	11·70	246·68	1·81
10	334·668	215·998	1·710	40·45	0·42	37·84	11·73	246·70	1·83
12	334·660	216·196	1·727	40·71	0·42	38·08	11·75	246·72	1·85
14	334·653	216·384	1·743	40·97	0·43	38·32	11·75	246·75	1·86
16	334·646	216·559	1·759	41·23	0·43	38·57	11·75	246·77	1·88
18	334·640	216·725	1·774	41·49	0·43	38·82	11·73	246·80	1·89
20	334·635	216·877	1·789	41·76	0·43	39·07	11·71	246·83	1·91
22	334·629	217·020	1·804	42·03	0·43	39·32	11·67	246·86	1·93
24	334·624	217·150	1·819	42·31	0·43	39·58	11·62	246·89	1·94
26	334·620	217·268	1·833	42·59	0·42	39·84	11·55	246·93	1·96
28	334·617	217·373	1·847	42·86	0·42	40·10	11·48	246·97	1·97
30	334·614	217·466	1·860	43·14	0·42	40·36	11·39	247·01	1·99
July 2	334·611	217·547	1·873	43·42	0·41	40·62	11·29	247·05	2·00
4	334·608	217·615	1·885	43·70	0·41	40·88	11·18	247·10	2·02
6	334·606	217·671	1·897	43·98	0·41	41·15	11·05	247·14	2·03
8	334·604	217·714	1·909	44·26	0·40	41·42	10·92	247·19	2·04
10	334·602	217·744	1·920	44·54	0·39	41·68	10·77	247·24	2·05
12	334·601	217·761	1·931	44·82	0·38	41·94	10·60	247·30	2·06
14	334·601	217·765	1·941	45·10	0·37	42·20	10·43	247·36	2·07
16	334·600	217·756	1·951	45·38	0·36	42·46	10·24	247·42	2·08
18	334·601	217·734	1·960	45·66	0·35	42·72	10·03	247·49	2·09
20	334·601	217·698	1·969	45·94	0·33	42·98	9·82	247·56	2·10
22	334·602	217·650	1·977	46·21	0·32	43·23	9·59	247·63	2·11
24	334·604	217·589	1·985	46·48	0·30	43·48	9·35	247·71	2·12
26	334·606	217·515	1·992	46·74	0·29	43·73	9·09	247·79	2·13
28	334·608	217·428	1·999	47·00	0·28	43·97	8·82	247·88	2·13
30	334·611	217·329	2·005	47·25	0·26	44·21	8·54	247·98	2·14
Aug. 1	334·614	217·216	2·010	47·50	0·25	44·44	8·25	248·09	2·15
3	334·618	217·092	2·014	47·74	0·23	44·67	7·95	248·21	2·15
5	334·622	216·957	2·018	47·97	0·21	44·89	7·63	248·35	2·16
7	334·627	216·809	2·022	48·20	0·19	45·11	7·30	248·50	2·16
9	334·633	216·651	2·025	48·42	0·17	45·31	6·96	248·66	2·16
11	334·639	216·482	2·027	48·64	0·16	45·51	6·61	248·83	2·16
13	334·646	216·302	2·028	48·84	0·14	45·70	6·25	248·99	2·17
15	334·653	216·113	2·029	49·03	0·13	45·88	5·88	249·17	2·17
17	334·661	215·914	2·030	49·21	0·11	46·05	5·50	249·39	2·17
19	334·670	215·704	+2·029	49·38	0·10	46·20	5·11	249·68	+2·17

Greenwich Mean.	Longitude of Σ's Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A—O.	B.
1903.	°	°	°	m	°	°
June 6	180·88	10·34	+0·59	41·580		
8	136·62	310·82	·60	41·324		
10	92·36	251·31	·60	41·066	204·265	+1·265
12	48·12	191·81	·60	40·808		
14	3·89	132·32	·60	40·550		
16	319·67	72·83	·60	40·293		
18	275·46	13·34	·60	40·035		
20	231·26	313·89	·60	39·778	205·168	1·309
22	187·07	254·45	·59	39·522		
24	142·90	195·02	·59	39·267		
26	98·74	135·60	·58	39·013		
28	54·59	76·19	·57	38·761		
30	10·45	16·79	·56	38·510	206·071	1·352
July 2	326·32	317·40	·55	38·261		
4	282·21	258·01	·54	38·015		
6	238·10	198·64	·53	37·773		
8	194·00	139·28	·52	37·533		
10	149·91	79·93	·50	37·294	206·975	1·396
12	105·83	20·59	·49	37·059		
14	61·77	321·27	·47	36·831		
16	17·72	261·96	·46	36·605		
18	333·68	202·66	·44	36·382		
20	289·65	143·37	·42	36·164	207·881	1·439
22	245·62	84·09	·40	35·951		
24	201·61	24·81	·38	35·744		
26	157·61	325·55	·36	35·542		
28	113·61	266·29	·34	35·346		
30	69·62	207·04	·32	35·156	208·786	1·481
Aug. 1	25·65	147·80	·30	34·972		
3	341·69	88·58	·28	34·794		
5	297·73	29·36	·26	34·623		
7	253·78	330·14	·23	34·461		
9	209·84	270·93	·21	34·305	209·691	1·524
11	165·90	211·73	·19	34·156		
13	121·96	152·54	·17	34·015		
15	78·03	93·35	·15	33·883		
17	34·10	34·16	·13	33·758		
19	350·18	334·98	+0·11	33·642	210·598	+1·566

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	
1903.	°	°	°	″	″	″	°	°	
Aug. 21	334·679	215·487	+2·028	49·54	0·09	46·34	4·71	249·98	+
23	334·689	215·262	2·026	49·68	0·07	46·48	4·31	250·41	
25	334·699	215·030	2·023	49·81	0·06	46·61	3·89	250·91	
27	334·711	214·791	2·020	49·94	0·05	46·72	3·48	251·51	
29	334·723	214·546	2·016	50·05	0·04	46·82	3·05	252·28	
31	334·736	214·296	2·011	50·14	0·03	46·91	2·62	253·33	
Sept. 2	334·749	214·042	2·006	50·22	0·02	46·98	2·19	254·78	
4	334·763	213·782	2·000	50·28	0·01	47·04	1·75	256·86	
6	334·777	213·521	1·994	50·33	0·01	47·08	1·33	260·29	
8	334·792	213·257	1·987	50·36	0·00	47·11	0·90	266·98	
10	334·807	212·992	1·980	50·37	0·00	47·13	0·51	284·84	
12	334·824	212·726	1·972	50·38	0·00	47·13	0·31	346·28	
14	334·842	212·460	1·964	50·36	0·00	47·11	0·59	35·35	
16	334·860	212·195	1·955	50·34	0·01	47·09	1·00	48·97	
18	334·878	211·932	1·946	50·30	0·01	47·05	1·42	54·62	
20	334·895	211·672	1·937	50·24	0·01	47·00	1·87	57·61	
22	334·913	211·415	1·927	50·17	0·02	46·93	2·30	59·45	
24	334·931	211·161	1·916	50·08	0·03	46·85	2·73	60·74	
26	334·949	210·913	1·905	49·97	0·04	46·76	3·15	61·68	
28	334·969	210·670	1·894	49·86	0·05	46·65	3·58	62·41	
30	334·989	210·434	1·882	49·73	0·06	46·53	3·99	62·96	
Oct. 2	335·008	210·205	1·870	49·58	0·07	46·39	4·40	63·41	
4	335·026	209·984	1·859	49·42	0·08	46·24	4·81	63·80	
6	335·044	209·770	1·847	49·26	0·10	46·09	5·20	64·14	
8	335·061	209·566	1·836	49·08	0·11	45·92	5·59	64·43	
10	335·077	209·372	1·825	48·89	0·13	45·74	5·96	64·68	
12	335·093	209·187	1·814	48·69	0·14	45·55	6·33	64·92	
14	335·109	209·012	1·802	48·48	0·16	45·36	6·68	65·10	
16	335·125	208·849	1·791	48·26	0·18	45·15	7·03	65·27	
18	335·139	208·697	1·779	48·03	0·20	44·94	7·36	65·43	
20	335·152	208·557	1·768	47·79	0·22	44·72	7·69	65·59	
22	335·163	208·429	1·757	47·55	0·24	44·49	8·00	65·73	
24	335·173	208·314	1·746	47·30	0·25	44·25	8·29	65·87	
26	335·184	208·211	1·736	47·04	0·27	44·01	8·58	66·01	
28	335·193	208·122	1·726	46·78	0·28	43·76	8·85	66·12	
30	335·201	208·046	1·716	46·51	0·29	43·51	9·11	66·22	
Nov. 1	335·207	207·983	1·707	46·24	0·31	43·25	9·35	66·31	
3	335·212	207·934	+1·698	45·96	0·32	42·99	9·58	66·40	+1

Greenwich Noon.	Longitude of Σ's Central Meridian. 9777°90 I.	8700°27 II.	Corr. for Phase.	Light-time.	A−O.	B.
1903.	°	°	°	m	″	″
Aug. 21	306·26	275·81	+0·10	33·535		
23	262·35	216·64	·08	33·437		
25	218·43	157·46	·06	33·348		
27	174·52	98·29	·05	33·267		
29	130·61	39·12	·04	33·196	211·505	+1·607
31	86·70	339·94	·03	33·137		
Sept. 2	42·79	280·77	·02	33·086		
4	358·87	221·59	·01	33·043		
6	314·95	162·41	+0·01	33·011		
8	271·03	103·23	·00	32·990	212·412	1·648
10	227·10	44·04	·00	32·978		
12	183·17	344·85	·00	32·975		
14	139·23	285·65	·00	32·983		
16	95·28	226·44	·00	33·001		
18	51·33	167·22	−0·01	33·029	213·321	1·689
20	7·37	108·00	·02	33·068		
22	323·40	48·77	·02	33·116		
24	279·41	349·53	·03	33·174		
26	235·42	290·28	·04	33·242		
28	191·41	231·01	·06	33·319	214·230	1·730
30	147·39	171·73	·07	33·405		
Oct. 2	103·36	112·44	·08	33·502		
4	59·32	53·14	·10	33·607		
6	15·26	353·83	·12	33·721		
8	331·19	294·50	·14	33·844	215 139	1·770
10	287·11	235·16	·16	33·976		
12	243·01	175·80	·17	34·117		
14	198·89	116·42	·19	34·266		
16	154·76	57·03	·21	34·423		
18	110·61	357·63	·24	34·586	216·050	1·809
20	66·45	298·21	·26	34·757		
22	22 27	238·76	·28	34·937		
24	338·07	179·30	·30	35·123		
26	293·85	119·83	·32	35·314		
28	249·62	60·34	·34	35·514	216·961	+1·848
30	205·37	0·83	·36	35·720		
Nov. 1	161·10	301·30	·38	35·931		
3	116·82	241·76	−0·40	36·147		

Greenwich Noon.	P.	L$_1$–O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.
1903.	°	°	°	″	″	″	°	°
Nov. 5	335·216	207·898	+1·689	45·68	0·34	42·73	9·80	66·48 +
7	335·218	207·877	1·681	45·40	0·35	42·47	10·00	66·56
9	335·219	207·869	1·673	45·12	0·36	42·21	10·19	66·63
11	335·219	207·874	1·665	44·83	0·37	41·94	10·37	66·69
13	335·218	207·894	1·658	44·54	0·38	41·67	10·53	66·75
15	335·215	207·926	1·651	44·25	0·38	41·40	10·68	66·80
17	333·211	207·973	1·645	43·96	0·39	41·13	10·82	66·85
19	335·206	208·034	1·639	43·67	0·40	40·86	10·94	66·90
21	335·199	208·108	1·634	43·38	0·40	40·60	11·05	66·95
23	335·191	208·195	1·629	43·10	0·40	40·33	11·15	66·99
25	335·182	208·295	1·625	42·82	0·41	40·07	11·23	67·03
27	335·172	208·410	1·622	42·54	0·41	39·80	11·30	67·07
29	335·161	208·536	1·619	42·26	0·41	39·54	11·35	67·11
Dec. 1	335·148	208·675	1·616	41·98	0·41	39·28	11·40	67·14
3	335·134	208·827	1·614	41·70	0·41	39·02	11·43	67·17
5	335·120	208·991	1·612	41·43	0·41	38·76	11·45	67·20
7	335·104	209·167	1·611	41·16	0·41	38·51	11·45	67·22
9	335·088	209·354	1·610	40·90	0·41	38·26	11·45	67·25
11	335·071	209·553	1·610	40·64	0·40	38·01	11·43	67·27
13	335·053	209·764	1·611	40·38	0·40	37·77	11·40	67·30
15	335·035	209·987	1·612	40·12	0·40	37·53	11·36	67·32
17	335·017	210·220	1·613	39·87	0·40	37·30	11·31	67·34
19	334·999	210·464	1·615	39·62	0·39	37·07	11·25	67·35
21	334·980	210·719	1·618	39·38	0·38	36·84	11·18	67·37
23	334·960	210·984	1·621	39·14	0·37	36·62	11·10	67·38
25	334·939	211·259	1·625	38·91	0·36	36·40	11·00	67·40
27	334·918	211·543	1·629	38·68	0·35	36·19	10·90	67·41
29	334·897	211·838	1·634	38·46	0·34	35·98	10·79	67·43
31	334·876	212·141	1·639	38·24	0·33	35·78	10·67	67·45
1904.								
Jan. 2	334·856	212·453	1·644	38·03	0·32	35·58	10·54	67·46
4	334·836	212·774	1·650	37·82	0·31	35·38	10·40	67·48
6	334·816	213·102	1·656	37·62	0·30	35·19	10·26	67·50
8	334·796	213·440	1·663	37·42	0·29	35·00	10·10	67·52
10	334·775	213·785	1·670	37·22	0·28	34·82	9·94	67·54
12	334·755	214·137	1·678	37·03	0·27	34·64	9·77	67·56
14	334·737	214·498	1·686	36·85	0·26	34·47	9·59	67·58
16	334·719	214·866	1·694	36·67	0·25	34·31	9·41	67·61
18	334·701	215·240	+1·703	36·50	0·24	34·15	9·22	67·63 +

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	B
1903	°	°	°	m	°	°
Nov. 5	72·52	182·20	−·42	36·368		
7	28·20	122·63	·44	36·594	217·872	+1·887
9	343·87	63·04	·45	36·824		
11	299·52	3·43	·47	37·058		
13	255·16	303·81	·48	37·296		
15	210·78	244·17	·50	37·539		
17	166·38	184·51	·51	37·785	218·783	1·925
19	121·97	124·84	·52	38·034		
21	77·54	65·15	·53	38·286		
23	33·10	5·45	·54	38·540		
25	348·64	305·73	·55	38·796		
27	304·17	246·00	·55	39·055	219·695	1·963
29	259·69	186·26	·56	39·314		
Dec. 1	215·19	126·51	·56	39·574		
3	170·68	66·74	·57	39·836		
5	126·16	6·96	·57	40·097		
7	81·63	307·16	·57	40·359	220·608	2·000
9	37·08	247·35	·57	40·621		
11	352·52	187·53	·57	40·883		
13	307·95	127·71	·56	41·146		
15	263·37	67·87	·56	41·407		
17	218·77	8·02	·55	41·667	221·522	+2·037
19	174·17	308·16	·55	41·926		
21	129·56	248·29	·54	42·183		
23	84·94	188·41	·54	42·439		
25	40·31	128·52	·53	42·694		
27	355·67	68·62	·52	42·946	222·434	2·074
29	311·02	8·71	·51	43·196		
31	266·36	308·80	·49	43·443		
1904						
Jan. 2	221·70	248·88	·48	43·688		
4	177·03	188·96	·47	43·929		
6	132·36	129·03	·46	44·166	223·347	2·109
8	87·68	69·09	·44	44·400		
10	43·00	9·14	·43	44·632		
12	358·31	309·19	·42	44·859		
14	313·62	249·24	·40	45·083		
16	268·92	189·28	·38	45·303	224·262	+2·145
18	224·21	129·31	−·37	45·518		

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.
1904.	°	°	°	″	″	″	°	°
Jan. 20	334·684	215·622	+1·712	36·33	0·22	33·99	9·02	67·66 +
22	334·668	216·010	1·721	36·17	0·21	33·84	8·81	67 69
24	334·653	216·404	1·731	36·01	0·20	33·69	8 60	67·73
26	334·639	216·804	1·741	35·85	0·19	33 55	8·38	67·77
28	334·625	217·210	1·751	35·70	0·18	33·41	8 16	67·81
30	334·612	217·621	1·762	35·55	0·17	33·28	7·93	67·86
Feb. 1	334·600	218·038	1·773	35·41	0·16	33·15	7·70	67·91
3	334·589	218·460	1·784	35·29	0·15	33·02	7·46	67·97
5	334·580	218·886	1·796	35·16	0·14	32 90	7·21	68 03
7	334·572	219·318	1·808	35·04	0·13	32·79	6·97	68·10
9	334·565	219·753	1·820	34·93	0·12	32·68	6·72	68·17
11	334·559	220·192	1·832	34·82	0·11	32·57	6·46	68·25
13	334·555	220·637	1·845	34·71	0·10	32·47	6·20	68·33
15	334·552	221 084	1·858	34·61	0·09	32·38	5·93	68·42
17	334·550	221·536	1·871	34·51	0·08	32·29	5·66	68·52
19	334·549	221·991	1·884	34·42	0·07	32·20	5·39	68·62
21	334·549	222·449	1·898	34·33	0·06	32·12	5·12	68·73
23	334·550	222 909	+1·912	34·25	0·06	32·04	4·84	68·84 +

The following is a list of the Greenwich Mean Times w the Zero Meridians of the two adopted systems cross the cer of the illuminated disc :—

System I.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d	h
Mar.	28	1	44·67	Apr.	3	5	24·01	Apr.	9	9	3·15	Apr.	15	12 4
		11	35·30			15	14·62			18	53·76			22 3
		21	25·93		4	1	5·23		10	4	44·37		16	8 2
	29	7	16·56			10	55·84			14	34·97			18 1
		17	7·19			20	46·45		11	0	25 58		17	4
	30	2	57·82		5	6	37·06			10	16·18			13 5
		12	48 44			16	27 67			20	6·79			23 4
		22	39·06		6	2	18·27		12	5	57·39		18	9 3
	31	8	29·68			12	8 88			15	47·99			19 2
		18	20·30			21	59·48		13	1	38·59		19	5 1
Apr.	1	4	10·92		7	7	50·09			11	29·19			15
		14	1·54			17	40 70			21	19·79		20	0 5
		23	52·16		8	3	31·32		14	7	10·39			10 4
	2	9	42·78			13	21·93			17	0·98			20 3
		19	33·39			23	12·54		15	2	51·58		21	6 3

Greenwich Noon.	Longitude of ℳ's Central Meridian. 877°90. I.	870°27 II.	Corr. for Phase.	Light-time.	A−O.	B.
1902.	°	°	°	m	°	°
Dec. 20	179·50	69·34	−·35	45·729		
22	134·78	9·37	·34	45·936		
24	90·06	309·39	·32	46·138		
26	45·34	249·41	·30	46·334	225·175	+2·179
28	0·62	189·43	·29	46·525		
30	315·90	129·44	·28	46·712		
Feb. 1	271·17	69·46	·26	46·893		
3	226·44	9·47	·24	47·068		
5	181·71	309·48	·23	47·238	226·089	2·213
7	136·98	249·49	·21	47·404		
9	92·24	189·50	·19	47·563		
11	47·51	129·51	·18	47·716		
13	2·78	69·52	·17	47·863		
15	318·05	9·53	·15	48·005	227·005	+2·247
17	273·31	309·53	·14	48·140		
19	228·58	249·54	·13	48·269		
21	183·84	189·54	·11	48·391		
23	139·10	129·54	−0·10	48·506		

System I.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d	h	m
Apr.	21	16	21·09	Apr.	29	1	31·63	May	6	10	41·97	May	13	19	52·10
	22	2	11·68			11	22·21			20	32·53		14	5	42·66
		12	2·27			21	12·79		7	6	23·10			15	33·21
		21	52·86		30	7	3·37			16	13·67		15	1	23·77
	23	7	43·45			16	53·95		8	2	4·23			11	14·32
		17	34·04	May	1	2	44·53			11	54·80			21	4·88
	24	3	24·63			12	35·11			21	45·36		16	6	55·44
		13	15·21			22	25·68		9	7	35·93			16	45·99
		23	5·80		2	8	16·26			17	26·49		17	2	36·55
	25	8	56·38			18	6·83		10	3	17·06			12	27·11
		18	46·97		3	3	57·41			13	7·62			22	17·66
	26	4	37·55			13	47·98			22	58·18		18	8	8·21
		14	28·14			23	38·55		11	8	48·74			17	58·76
	27	0	18·72		4	9	29·12			18	39·30		19	3	49·31
		10	9·31			19	19·69		12	4	29·86			13	39·86
		19	59·89		5	5	10·26			14	20·42			23	30·41
	28	5	50·47			15	0·83		13	0	10·98		20	9	20·96
		15	41·05		6	0	51·40			10	1·54			19	11·50

System I.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d
May	21	5	2·05	June	5	19	2·33	June	21	9	1·67	July	6
		14	52·60		6	4	52·85			18	52·17		7
	22	0	43·14			14	43·37		22	4	42·66		
		10	33·69		7	0	33·89			14	33·16		8
		20	24·23			10	24·41		23	0	23·65		
	23	6	14·77			20	14·93			10	14·15		9
		16	5·31		8	6	5·45			20	4·64		
	24	1	55·85			15	55·97		24	5	55·13		
		11	46·39		9	1	46·49			15	45·62		10
		21	36·93			11	37·01		25	1	36·11		
	25	7	27·47			21	27·52			11	26·60		11
		17	18·00		10	7	18·04			21	17·09		
	26	3	8·54			17	8·56		26	7	7·58		
		12	59·08		11	2	59·07			16	58·07		12
		22	49·61			12	49·58		27	2	48·56		
	27	8	40·15			22	40·09			12	39·04		13
		18	30·69		12	8	30·60			22	29·53		
	28	4	21·23			18	21·11		28	8	20·02		
		14	11·77		13	4	11·62			18	10·50		14
	29	0	2·31			14	2·13		29	4	0·99		
		9	52·85			23	52·64			13	51·47		15
		19	43·38		14	9	43·15			23	41·95		
	30	5	33·92			19	33·65		30	9	32·43		
		15	24·45		15	5	24·16			19	22·91		16
	31	1	14·98			15	14·67	July	1	5	13·39		
		11	5·51		16	1	5·17			15	3·87		17
		20	56·04			10	55·68		2	0	54·35		
June	1	6	46·57			20	46·18			10	44·82		18
		16	37·10		17	6	36·68			20	35·30		
	2	2	27·63			16	27·19		3	6	25·78		
		12	18·15		18	2	17·69			16	16·25		19
		22	8·68			12	8·19		4	2	6·72		
	3	7	59·21			21	58·69			11	57·19		20
		17	49·73		19	7	49·19			21	47·66		
	4	3	40·25			17	39·69		5	7	38·13		
		13	30·77		20	3	30·18			17	28·60		21
		23	21·29			13	20·68		6	3	19·07		
	5	9	11·81			23	11·18			13	9·54		22

System I.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d	h	m
July	22	12	57·39	Aug.	7	2	53·84	Aug.	22	16	49·63	Sept.	7	6	45·10
		22	47·83			12	44·26		23	2	40·04			16	35·51
	23	8	38·27			22	34·69			12	30·45		8	2	25·92
		18	28·71		8	8	25·11			22	20·86			12	16·33
	24	4	19·15			18	15·54		24	8	11·26			22	6·74
		14	9·59		9	4	5·96			18	1·67		9	7	57·15
	25	0	0·03			13	56·38		25	3	52·08			17	47·56
		9	50·47			23	46·80			13	42·49		10	3	37·97
		19	40·91		10	9	37·22			23	32·90			13	28·38
	26	5	31·35			19	27·64		26	9	23·31			23	18·79
		15	21·79		11	5	18·05			19	13·72		11	9	9·20
	27	1	12·23			15	8·47		27	5	4·13			18	59·61
		11	2·67		12	0	58·89			14	54·54		12	4	50·02
		20	53·11			10	49·30		28	0	44·95			14	40·43
	28	6	43·55			20	39·72			10	35·36		13	0	30·84
		16	33·99		13	6	30·13			20	25·77			10	21·25
	29	2	24·43			16	20·54		29	6	16·18			20	11·66
		12	14·86		14	2	10·96			16	6·59		14	6	2·07
		22	5·30			12	1·37		30	1	56·99			15	52·48
	30	7	55·73			21	51·78			11	47·40		15	1	42·90
		17	46·16		15	7	42·20			21	37·80			11	33·31
	31	3	36·59			17	32·61		31	7	28·21			21	23·73
		13	27·02		16	3	23·03			17	18·61		16	7	14·15
		23	17·45			13	13·44	Sept.	1	3	9·02			17	4·57
Aug.	1	9	7·88			23	3·86			12	59·42		17	2	54·99
		18	58·31		17	8	54·27			22	49·82			12	45·41
	2	4	48·74			18	44·69		2	8	40·23			22	35·83
		14	39·16		18	4	35·10			18	30·63		18	8	26·25
	3	0	29·59			14	25·52		3	4	21·03			18	16·67
		10	20·01		19	0	15·93			14	11·44		19	4	7·10
		20	10·43			10	6·34		4	0	1·84			13	57·52
	4	6	0·85			19	56·76			9	52·24			23	47·95
		15	51·27		20	5	47·17			19	42·65		20	9	38·37
	5	1	41·70			15	37·58		5	5	33·06			19	28·80
		11	32·13		21	1	27·99			15	23·47		21	5	19·22
		21	22·56			11	18·40		6	1	13·88			15	9·65
	6	7	12·98			21	8·81			11	4·29		22	1	0·07
		17	3·41		22	6	59·22			20	54·69			10	50·50

System I.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d
Sept.	22	20	40·93	Oct.	8	10	37·95	Oct.	24	0	36·46	Nov.	8
	23	6	31·36			20	28·42			10	26·97		9
		16	21·79		9	6	18·89			20	17·48		
	24	2	12·22			16	9·36		25	6	7·99		
		12	2·65		10	1	59·83			15	58·51		10
		21	53·09			11	50·30		26	1	49·02		
	25	7	43·52			21	40·77			11	39·54		11
		17	33·96		11	7	31·24			21	30·06		
	26	3	24·40			17	21·71		27	7	20·58		
		13	14·84		12	3	12·18			17	11·10		12
		23	5·28			13	2·66		28	3	1·62		
	27	8	55·72			22	53·13			12	52·14		13
		18	46·16		13	8	43·61			22	42·66		
	28	4	36·60			18	34·09		29	8	33·19		
		14	27·04		14	4	24·57			18	23·71		14
	29	0	17·49			14	15·05		30	4	14·24		
		10	7·93		15	0	5·54			14	4·76		15
		19	58·38			9	56·02			23	55·29		
	30	5	48·83			19	46·51		31	9	45·82		
		15	39·27		16	5	37·00			19	36·35		16
Oct.	1	1	29·72			15	27·49	Nov.	1	5	26·88		
		11	20·17		17	1	17·98			15	17·42		17
		21	10·62			11	8·47		2	1	7·95		
	2	7	1·07			20	58·96			10	58·49		18
		16	51·52		18	6	49·45			20	49·03		
	3	2	41·97			16	39·94		3	6	39·56		
		12	32·42		19	2	30·44			16	30·10		19
		22	22·87			12	20·94		4	2	20·64		
	4	8	13·33			22	11·44			12	11·18		20
		18	3·79		20	8	1·94			22	1·72		
	5	3	54·25			17	52·43		5	7	52·26		
		13	44·71		21	3	42·93			17	42·80		21
		23	35·17			13	33·43		6	3	33·34		
	6	9	25·63			23	23·93			13	23·89		22
		19	16·09		22	9	14·44			23	14·43		
	7	5	6·55			19	4·94		7	9	4·98		
		14	57·02		23	4	55·45			18	55·53		23
	8	0	47·48			14	45·95		8	4	46·08		

System I.

1903.	d	h	m
Nov.	24	4	38·34
		14	28·93
	25	0	19·52
		10	10·11
		20	0·70
	26	5	51·29
		15	41·89
	27	1	32·48
		11	23·08
		21	13·67
	28	7	4·27
		16	54·87
	29	2	45·47
		12	36·08
		22	26·68
	30	8	17·28
		18	7·88
Dec.	1	3	58·48
		13	49·09
		23	39·70
	2	9	30·31
		19	20·92
	3	5	11·53
		15	2·14
	4	0	52·75
		10	43·36
		20	33·97
	5	6	24·58
		16	15·19
	6	2	5·80
		11	56·41
		21	47·03
	7	7	37·64
		17	28·25
	8	3	18·87
		13	9·49
		23	0·10
	9	8	50·72

1903.	d	h	m
Dec.	9	18	41·34
	10	4	31·96
		14	22·58
	11	0	13·20
		10	3·82
		19	54·44
	12	5	45·06
		15	35·68
	13	1	26·31
		11	16·93
		21	7·56
	14	6	58·18
		16	48·81
	15	2	39·44
		12	30·07
		22	20·70
	16	8	11·33
		18	1·96
	17	3	52·59
		13	43·22
		23	33·86
	18	9	24·49
		19	15·13
	19	5	5·76
		14	56·40
	20	0	47·04
		10	37·68
		20	28·32
	21	6	18·96
		16	9·60
	22	2	0·24
		11	50·88
		21	41·53
	23	7	32·17
		17	22·81
	24	3	13·45
		13	4·10
		22	54·74

1903.	d	h	m
Dec.	25	8	45·38
		18	36·03
	26	4	26·67
		14	17·32
	27	0	7·97
		9	58·61
		19	49·26
	28	5	39·91
		15	30·55
	29	1	21·20
		11	11·85
		21	2·50
	30	6	53·15
		16	43·80
	31	2	34·45
		12	25·10
		22	15·75
1904.			
Jan.	1	8	6·40
		17	57·05
	2	3	47·70
		13	38·35
		23	29·00
	3	9	19·66
		19	10·31
	4	5	0·96
		14	51·62
	5	0	42·27
		10	32·93
		20	23·58
	6	6	14·24
		16	4·90
	7	1	55·56
		11	46·21
		21	36·87
	8	7	27·52
		17	18·18
	9	3	8·84

1904.	d	h	m
Jan.	9	12	59·50
		22	50·16
	10	8	40·82
		18	31·48
	11	4	22·14
		14	12·80
	12	0	3·46
		9	54·12
		19	44·78
	13	5	35·44
		15	26·10
	14	1	16·76
		11	7·43
		20	58·09
	15	6	48·75
		16	39·42
	16	2	30·08
		12	20·74
		22	11·41
	17	8	2·07
		17	52·74
	18	3	43·41
		13	34·07
		23	24·74
	19	9	15·41
		19	6·08
	20	4	56·74
		14	47·41
	21	0	38·08
		10	28·75
		20	19·42
	22	6	10·09
		16	0·76
	23	1	51·42
		11	42·09
		21	32·76
	24	7	23·42
		17	14·09

System I.

1904.	d	h	m	1904.	d	h	m	1904.	d	h	m	1904.	d	
Jan.	25	3	4·76	Feb.	1	22	7·51	Feb.	9	7	19·63	Feb.	16	1
		12	55·43		2	7	58·18			17	10·31		17	
		22	46·10			17	48·85		10	3	0·99			1
	26	8	36·77		3	3	39·52			12	51·66			2
		18	27·44			13	30·19			22	42·34		18	
	27	4	18·11			23	20·87		11	8	33·02			1
		14	8·78		4	9	11·54			18	23·69		19	
		23	59·45			19	2·21		12	4	14·37			1
	28	9	50·12		5	4	52·89			14	5·04			2
		19	40·79			14	43·56			23	55·72		20	
	29	5	31·46		6	0	34·23		13	9	46·39			1
		15	22·13			10	24·90			19	37·07		21	
	30	1	12·80			20	15·58		14	5	27·74			1
		11	3·47		7	6	6·25			15	18·42		22	
		20	54·15			15	56·93		15	1	9·09			1
	31	6	44·82		8	1	47·60			10	59·77			2
		16	35·49			11	38·28			20	50·44		23	
Feb.	1	2	26·17			21	28·96		16	6	41·12			1
		12	16·84											

System II.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d	
Mar.	28	1	39·63	Apr.	4	2	28·21	Apr.	11	3	16·64	Apr.	18	
		11	35·43			12	24·00			13	12·42			1
		21	31·24			22	19·79			23	8·21			2
	29	7	27·04		5	8	15·58		12	9	3·99		19	
		17	22·84			18	11·37			18	59·77			1
	30	3	18·64		6	4	7·16		13	4	55·55		20	
		13	14·44			14	2·95			14	51·33			1
		23	10·24			23	58·74		14	0	47·11		21	
	31	9	6·04		7	9	54·53			10	42·89			1
		19	1·84			19	50·32			20	38·66			2
Apr.	1	4	57·64		8	5	46·12		15	6	34·44		22	
		14	53·44			15	41·91			16	30·21			1
	2	0	49·23		9	1	37·70		16	2	25·98		23	
		10	45·03			11	33·49			12	21·75			1
		20	40·82			21	29·28			22	17·52			2
	3	6	36·62		10	7	25·07		17	8	13·29		24	
		16	32·41			17	20·86			18	9·07			1

System II.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d	h	m
Apr.	25	4	52·95	May	10	22	11·53	May	26	15	29·21	June	11	8	45·94
		14	48·71		11	8	7·27		27	1	24·92			18	41·63
	26	0	44·47			18	2·01			11	20·63		12	4	37·32
		10	40·23		12	3	58·75			21	16·35			14	33·01
		20	35·99			13	54·49		28	7	12·06		13	0	28·70
	27	6	31·75			23	50·22			17	7·77			10	24·39
		16	27·52		13	9	45·96		29	3	3·48			20	20·07
	28	2	23·28			19	41·70			12	59·19		14	6	15·76
		12	19·04		14	5	37·43			22	54·90			16	11·45
		22	14·80			15	33·17		30	8	50·61		15	2	7·13
	29	8	10·56		15	1	28·90			18	46·32			12	2·81
		18	6·32			11	24·64		31	4	42·03			21	58·50
	30	4	2·08			21	20·37			14	37·74		16	7	54·18
		13	57·84		16	7	16·10	June	1	0	33·45			17	49·86
		23	53·59			17	11·84			10	29·16		17	3	45·55
May	1	9	49·35		17	3	7·57			20	24·86			13	41·23
		19	45·11			13	3·30		2	6	20·57			23	36·91
	2	5	40·86			22	59·04			16	16·28		18	9	32·59
		15	36·61		18	8	54·77		3	2	11·98			19	28·27
	3	1	32·36			18	50·50			12	7·69		19	5	23·95
		11	28·11		19	4	46·23			22	3·39			15	19·63
		21	23·86			14	41·96		4	7	59·10		20	1	15·30
	4	7	19·61		20	0	37·69			17	54·80			11	10·98
		17	15·36			10	33·41		5	3	50·50			21	6·65
	5	3	11·11			20	29·14			13	46·21		21	7	2·33
		13	6·86		21	6	24·86			23	41·91			16	58·00
		23	2·60			16	20·59		6	9	37·61		22	2	53·67
	6	8	58·34		22	2	16·31			19	33·31			12	49·34
		18	54·09			12	12·03		7	5	29·00			22	45·01
	7	4	49·83			22	7·75			15	24·70		23	8	40·68
		14	45·58		23	8	3·47		8	1	20·40			18	36·35
	8	0	41·32			17	59·19			11	16·09		24	4	32·02
		10	37·07		24	3	54·91			21	11·79			14	27·68
		20	32·81			13	50·63		9	7	7·48		25	0	23·35
	9	6	28·56			23	46·35			17	3·18			10	19·01
		16	24·30		25	9	42·06		10	2	58·87			20	14·68
	10	2	20·04			19	37·78			12	54·56		26	6	10·34
		12	15·79		26	5	33·49			22	50·25			16	6·00

System II.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d	
June	27	2	1·67	July	12	19	16·40	July	28	12	30·10	Aug.	13	
		11	57·33		13	5	12·03			22	25·71			1
		21	52·99			15	7·67		29	8	21·32		14	
	28	7	48·66		14	1	3·30			18	16·93			1
		17	44·32			10	58 93		30	4	12·54			2
	29	3	39·98			20	54·56			14	8·15		15	
		13	35·64		15	6	50·19		31	0	3·76			1
		23	31·30			16	45·82			9	59·37		16	
	30	9	26·96		16	2	41·45			19	54·97			1
		19	22·62			12	37·08	Aug.	1	5	50·58			2
July	1	5	18·28			22	32·71			15	46·18		17	
		15	13·94		17	8	28·34		2	1	41·79			1
	2	1	9·59			18	23·97			11	37·39		18	
		11	5·25		18	4	19·59			21	32·99			1
		21	0·90			14	15·22		3	7	28·59		19	
	3	6	56·56		19	0	10·85			17	24·19			1
		16	52·21			10	6·47		4	3	19·79			2
	4	2	47·86			20	2·10			13	15·39		20	
		12	43·51		20	5	57·72			23	10·99			1
		22	39·16			15	53·35		5	9	6·60		21	
	5	8	34·81		21	1	48·97			19	2·21			1
		18	30·46			11	44·59		6	4	57·81			2
	6	4	26·11			21	40·22			14	53·41		22	
		14	21·76		22	7	35·84		7	0	49·02			1
	7	0	17·41			17	31·46			10	44·62		23	
		10	13·06		23	3	27·08			20	40·22			1
		20	8·71			13	22·70		8	6	35·82			2
	8	6	4·35			23	18·32			16	31·42		24	
		16	0·00		24	9	13·93		9	2	27·02			1
	9	1	55·64			19	9·55			12	22·62		25	
		11	51·29		25	5	5·17			22	18·21			1
		21	46·93			15	0·78		10	8	13·81		26	
	10	7	42·57		26	0	56·40			18	9·40			1
		17	38·21			10	52·02		11	4	5·00			2
	11	3	33·85			20	47·63			14	0·59		27	
		13	29·49		27	6	43·25			23	56·18			
		23	25·12			16	38·87		12	9	51·78		28	
	12	9	20·76		28	2	34·48			19	47·37			

System II.

1903.	d	h	m
Aug.	28	22	55·24
	29	8	50·82
		18	46·41
	30	4	41·99
		14	37·57
	31	0	33·16
		10	28·74
		20	24·32
Sept.	1	6	19·90
		16	15·48
	2	2	11·06
		12	6·64
		22	2·22
	3	7	57·80
		17	53·39
	4	3	48·97
		13	44·55
		23	40·14
	5	9	35·72
		19	31·31
	6	5	26·89
		15	22·48
	7	1	18·06
		11	13·65
		21	9·23
	8	7	4·82
		17	0·40
	9	2	55·99
		12	51·57
		22	47·16
	10	8	42·74
		18	38·33
	11	4	33·91
		14	29·50
	12	0	25·08
		10	20·67
		20	16·25
	13	6	11·84

1903.	d	h	m
Sept.	13	16	7·42
	14	2	3·01
		11	58·60
		21	54·19
	15	7	49·78
		17	45·37
	16	3	40·97
		13	36·56
		23	32·16
	17	9	27·75
		19	23·35
	18	5	18·95
		15	14·54
	19	1	10·14
		11	5·74
		21	1·34
	20	6	56·94
		16	52·54
	21	2	48·14
		12	43·74
		22	39·34
	22	8	34·95
		18	30·55
	23	4	26·16
		14	21·76
	24	0	17·37
		10	12·98
		20	8·59
	25	6	4·20
		15	59·81
	26	1	55·42
		11	51·03
		21	46·65
	27	7	42·26
		17	37·88
	28	3	33·50
		13	29·11
		23	24·73

1903.	d	h	m
Sept.	29	9	20·35
		19	15·98
	30	5	11·60
		15	7·22
Oct.	1	1	2·85
		10	58·47
		20	54·10
	2	6	49·72
		16	45·35
	3	2	40·98
		12	36·61
		22	32·24
	4	8	27·87
		18	23·51
	5	4	19·14
		14	14·78
	6	0	10·42
		10	6·05
		20	1·69
	7	5	57·33
		15	52·97
	8	1	48·61
		11	44·25
		21	39·90
	9	7	35·54
		17	31·19
	10	3	26·83
		13	22·48
		23	18·13
	11	9	13·77
		19	9·42
	12	5	5·07
		15	0·73
	13	0	56·38
		10	52·03
		20	47·69
	14	6	43·34
		16	39·00

1903.	d	h	m
Oct.	15	2	34·66
		12	30·32
		22	25·98
	16	8	21·65
		18	17·31
	17	4	12·98
		14	8·65
	18	0	4·32
		9	59·99
		19	55·66
	19	5	51·33
		15	47·01
	20	1	42·68
		11	38·36
		21	34·04
	21	7	29·71
		17	25·39
	22	3	21·07
		13	16·76
		23	12·44
	23	9	8·13
		19	3·81
	24	4	59·50
		14	55·19
	25	0	50·87
		10	46·56
		20	42·25
	26	6	37·95
		16	33·64
	27	2	29·33
		12	25·03
		22	20·72
	28	8	16·42
		18	12·12
	29	4	7·82
		14	3·52
		23	59·23
	30	9	54·93

System II.

1903.	d	h	m	1903.	d	h	m	1903.	d	h	m	1903.	d
Oct.	30	19	50·64	Nov.	15	13	8·24	Dec.	1	6	27·35	Dec.	16
	31	5	46·34			23	3·99			16	23·13		17
		15	42·05		16	8	59·74		2	2	18·92		
Nov.	1	1	37·76			18	55·49			12	14·71		18
		11	33·47		17	4	51·24			22	10·49		
		21	29·18			14	46·99		3	8	6·28		19
	2	7	24·89		18	0	42·74			18	2·07		
		17	20·61			10	38·50		4	3	57·85		
	3	3	16·32			20	34·25			13	53·64		20
		13	12·04		19	6	30·01			23	49·43		
		23	7·75			16	25·77		5	9	45·21		21
	4	9	3·47		20	2	21·53			19	41·00		
		18	59·19			12	17·29		6	5	36·79		
	5	4	54·91			22	13·05			15	32·59		22
		14	50·63		21	8	8·82		7	1	28·38		
	6	0	46·35			18	4·58			11	24·17		23
		10	42·08		22	4	0·35			21	19·97		
		20	37·80			13	56·11		8	7	15·76		24
	7	6	33·53			23	51·88			17	11·56		
		16	29·25		23	9	47·64		9	3	7·35		
	8	2	24·98			19	43·41			13	3·15		25
		12	20·71		24	5	39·17			22	58·95		
		22	16·43			15	34·94		10	8	54·75		26
	9	8	12·16		25	1	30·71			18	50·55		
		18	7·89			11	26·48		11	4	46·35		
	10	4	3·63			21	22·25			14	42·16		27
		13	59·36		26	7	18·02		12	0	37·96		
		23	55·09			17	13·80			10	33·76		28
	11	9	50·83		27	3	9·57			20	29·57		
		19	46·56			13	5·34		13	6	25·37		
	12	5	42·30			23	1·12			16	21·17		29
		15	38·04		28	8	56·89		14	2	16·98		
	13	1	33·78			18	52·67			12	12·78		30
		11	29·52		29	4	48·45			22	8·58		
		21	25·27			14	44·23		15	8	4·39		31
	14	7	21·01		30	0	40·01			18	0·19		
		17	16·75			10	35·79		16	3	56·00		
	15	3	12·50			20	31·57			13	51·81		

System II.

1904.	d	h	m	1904.	d	h	m	1904.	d	h	m	1904.	d	h	m
Jan.	1	7	13·05	Jan.	14	22	55·67	Jan.	28	14	38·63	Feb.	10	20	25·93
		17	8·88		15	8	51·52		29	0	34·48		11	6	21·79
	2	3	4·71			18	47·36			10	30·34			16	17·64
		13	0·54		16	4	43·20			20	26·19		12	2	13·50
		22	56·37			14	39·05		30	6	22·04			12	9·35
	3	8	52·20		17	0	34·89			16	17·90			22	5·21
		18	48·03			10	30·74		31	2	13·75		13	8	1·06
	4	4	43·87			20	26·58			12	9·60			17	56·92
		14	39·70		18	6	22·43			22	5·46		14	3	52·78
	5	0	35·53			16	18·28	Feb.	1	8	1·31			13	48·63
		10	31·37		19	2	14·12			17	57·16			23	44·49
		20	27·20			12	9·97		2	3	53·01		15	9	40·35
	6	6	23·04			22	5·82			13	48·86			19	36·20
		16	18·87		20	8	1·66			23	44·71		16	5	32·06
	7	2	14·71			17	57·51		3	9	40·56			15	27·91
		12	10·55		21	3	53·36			19	36·41		17	1	23·77
		22	6·38			13	49·21		4	5	32·26			11	19·62
	8	8	2·22			23	45·06			15	28·12			21	15·48
		17	58·06		22	9	40·90		5	1	23·97		18	7	11·33
	9	3	53·90			19	36·75			11	19·82			17	7·19
		13	49·74		23	5	32·59			21	15·68		19	3	3·04
		23	45·58			15	28·44		6	7	11·53			12	58·90
	10	9	41·42		24	1	24·28			17	7·38			22	54·75
		19	37·26			11	20·13		7	3	3·24		20	8	50·61
	11	5	33·10			21	15·98			12	59·09			18	46·46
		15	28·95		25	7	11·83			22	54·94		21	4	42·32
	12	1	24·79			17	7·68		8	8	50·80			14	38·17
		11	20·63		26	3	3·53			18	46 65		22	0	34·03
		21	16·47			12	59·38		9	4	42·51			10	29·88
	13	7	12·31			22	55·23			14	38·36			20	25·74
		17	8·15		27	8	51·08		10	0	34·22		23	6	21·59
	14	3	3·99			18	46·93			10	30·08			16	17·45
		12	59·83		28	4	42·78								

The quantities in the ephemeris are to be interpolated directly for the times for which they are required, the equation of light having been already applied.

The position of *Jupiter's* North Pole is assumed to be R.A. $17^h\ 51^m\ 58^s{\cdot}68$, N.P.D. 25° 26′ 13″·2 at the beginning of 1903,

and R.A. $17^h\ 51^m\ 58^s{\cdot}91$, N.P.D. 25° 26′ 13″·6 at the beginning of 1904.

These values differ slightly from those used in former years, as I have now included the correction for precessional shift of *Jupiter's* equator. The effect of this alteration on physical observations of the planet is, however, altogether negligible.

P denotes the position-angle of the northern extremity of *Jupiter's* axis, reckoned eastward from the northernmost point of the disc.

L−O+180°, A−O+180° are the jovicentric right ascensions of the Earth and Sun respectively, reckoned in the plane of the planet's equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere; B, *B* are the jovicentric declinations of the Earth and Sun above the planet's equator.

The adopted values of the diameters at distance 5·20 are: Equatorial, 38″·419; Polar, 35″·945. The sources from which these values are derived were given two years ago.

The assumed time for light to traverse the unit distance is $498^s{\cdot}92$, this being the same value as that used by Mr. Marth.

d denotes the jovicentric angle between the Earth and Sun.

Q denotes the position-angle of the point of greatest phase, and is reckoned eastward from the northernmost point of the disc. It also gives the position-angle of the shadows of the satellites measured from the satellites themselves.

B′ is obtained from B by the formula $\tan B' = \sec \epsilon_0 \tan B$, where $\sec \epsilon_0 = \frac{a}{b} = \frac{15{\cdot}53}{14{\cdot}53}$. Since B, B′ can never exceed some 3°, we may take the tangents as proportionate to the angles. Hence it suffices in practice to find B′ by the formula $B' = \frac{15{\cdot}53}{14{\cdot}53} B$. B′ is the eccentric angle of the centre of the disc. If we call B″ the jovigraphical latitude of the centre of the disc, then we can find B″ by the formulæ:

$$\tan B'' = \sec^2 \epsilon_0 \tan B \quad \text{or} \quad \tan B'' = \sec \epsilon_0 \tan B'$$

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero-meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians which bisect the illuminated disc.

The sidereal periods of rotation corresponding to the two adopted systems are $9^h\ 50^m\ 30^s{\cdot}004$, $9^h\ 55^m\ 40^s{\cdot}632$.

The longitude of the Red Spot, after steadily increasing for many years, was stationary in 1901. In the present year it has diminished very considerably. Mr. H. J. Townshend determined it to be 42°·0 on July 17, and this value is approximately confirmed by other observers. There seems to be reason to believe that the change in its rate of rotation was somewhat sudden, but I have not received enough observations to settle this point—

The spot will probably follow the zero meridian of System II. by about one hour at the commencement of the present ephemeris, but a definite forecast of its behaviour is not possible.

The orbits of the satellites were turned edgewise to us in the present year. L. Bartlett, of 3021 Eads Ave., St. Louis, Mo., reports in the *English Mechanic* for November 7 an observation of the rare phenomenon of the eclipse of I. by the shadow of III. on October 19. The shadows were both on the disc of *Jupiter* at the time, and were seen to become merged into one. On turning to satellite I. it was seen to be losing light rapidly, and at $8^h\ 30^m$ became very faint, but regained its full light 10^m later. (I presume the time used is that of meridian 90° W.) The aperture of the telescope employed was $6\frac{1}{2}$ inches.

The *English Mechanic* for November 21, p. 316, states that mutual occultations of satellites were observed in the island of Syra on August $10^d\ 8^h\ 55^m$ G.M.T., August $13^d\ 7^h\ 35^m$ G.M.T., September $6^d\ 9^h\ 5^m$ G.M.T. The name of the observer and size of instrument employed are, however, not stated, so that we cannot be sure that the phenomena were not merely very close appulses.

A list of times of elongation of the fifth satellite is given in the *Connaissance des Temps*.

It may be mentioned here that the *Connaissance des Temps* for 1899 and following years gives ephemerides for the satellites of *Mars*, *Saturn*, *Uranus*, and *Neptune* in the same form as those formerly contributed to the *Monthly Notices* by Mr. Marth.

I have received a series of longitudes of the Great Red Spot from Mr. W. F. Denning, from which the following mean positions are deduced :—

Date.	Longitude (System II.)	No. of Obs.	Date.	Longitude (System II.)	No. of Obs.
	°			°	
May 23	45·1	3	Sept. 15	39·2	4
July 4	43·9	4	Oct. 13	38·1	4
Aug. 16	41·1	5	Nov. 17	37·9	4

These seem to indicate a somewhat sudden diminution of the longitude towards the end of May. The longitude continued to diminish rapidly throughout the summer, but apparently became nearly steady in October and November.

Mr. Denning found the mean rotation period of the equatorial spots in 1901 to be $9^h\ 50^m\ 29^s{\cdot}1$, and estimates that this year will give approximately the same value.

Benvenue, 55 *Ulundi Road*, *Blackheath*, *S.E.*:
1902 *December* 8.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

Henry Bourget, D.-ès-Sc., Astronome-adjoint à l'Observatoire de Toulouse, 20 Rue Saint Jacques, Toulouse ;
Major John Cassells, J.P., 154 Queen's Drive, Crosshill, Glasgow ;
Patrick Sinclair Hardie, M.A., B.Sc., 305 Onslow Drive, Dennistoun, Glasgow ; and
Richard Kerr, F.G.S., 13 Ormiston Road, Greenwich, S.E.,

were balloted for and duly elected Fellows of the Society.

Seventy-eight presents were announced as having been received since the last meeting, including amongst others :—

Two drawings of the total Solar Eclipse of 1901 May 18, made from negatives taken at Mauritius with the Newbegin telescope, presented by Mrs. Maunder ; lantern slide from photograph of a Leonid Meteor, taken 1901 November 14, at the Goodsell Observatory, Carleton College, Minn., presented by W. W. Payne ; N. M. Kam, Catalog von Sternen deren Oerter durch selbständige Meridian Beobachtungen bestimmt worden sind, herausgegeben von H. G. van de Sande Bakhuyzen, presented by the Amsterdam Academy.

Preliminary Note on the Possible Existence of Two Independent Stellar Systems. By F. A. Bellamy and H. H. Turner.

The publication of the above paper is deferred, as the authors find some numerical corrections necessary.

Statistics of Stars in a Zone of 5° from +65° to +70° Decl. counted on Photographs for the Astrographic Chart and Catalogue at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

An important use to which the long-exposure photographs for the astrographic chart can be immediately put is that of star gauging. In combination with counts of the number of stars shown with shorter exposures, these photographs give down to their limit information of a very interesting and complete character as to the distribution of the stars.

The following paper gives the results of these counts for the zone of 5° in width between +65° and +70° Decl.

The photographs were taken with the astrographic equatorial of 33 centimetres (or 13-inch) aperture and $3^m{\cdot}43$ (or 11-foot 3-inch) focus, and were usually obtained when the field photographed was within one hour of the meridian at upper culmination, and never more than one hour and a half from it. The most sensitive plates available were used—generally Ilford Special Rapid or Barnet Rocket plates. The chart plates have an exposure of 40^m, the catalogue plates three exposures of 6^m, 3^m, and 20^s respectively. Plates on any night are not considered satisfactory, and are rejected unless images of $9^m{\cdot}0$ stars appear with the exposure of 20^s on the catalogue plate.

In the counting of the chart plates with 40^m exposure the same plan is followed as in the measurement of the catalogue plates with the duplex micrometer; that is, the same field of the sky (usually of one square degree) is simultaneously examined on two plates. For example, the count of stars in the part of the sky lying between 65° and 66° of declination and between $0^h\ 0^m$ and $0^h\ 9^m$ of right ascension is made at the same time for the two plates whose centres are R.A. $0^h\ 9^m$ Decl. 65°, and R.A. $0^h\ 0^m$ Decl. 66°. The number of stars seen on both plates is counted, as well as the additional stars seen (with certainty) on one plate only. The counts are all made in duplicate (by two observers independently).

The counts of the stars shown on the catalogue plates are taken from the printed, but as yet unpublished, volume of the measures for the Greenwich Astrographic Catalogue Decl. +64° to +72°. In this volume the stars which are shown with an exposure of 20^s are indicated, as well as those stars which are shown with exposures of 3^m and 6^m. In the following table no discrimination has been made between the 6^m and 3^m exposures, but it is necessary to state that images of stars with 6^m exposure (which were not shown with 3^m) have not been measured unless

the star was shown on both plates. The possible combinations are :—

(i.) 6^m and 3^m images shown on both plates.
(ii.) 6^m and 3^m images shown on one plate, but only 6^m image on the other.
(iii.) 6^m and 3^m images on one plate, but the star not shown on the other.
(iv.) 6^m image, but not 3^m image shown on both plates.
(v.) 6^m image shown on one plate but not on the other.

In the fifth of these cases the image has not been measured, and consequently these cases are not included in the counts.

The following table gives the number of stars for areas of one degree in declination and 45^m in right ascension, these numbers being usually the sum of five different areas counted on six different plates, three in one zone and three in the zone next to it. This summation tends to smooth the inequalities due to the varying conditions of the nights when the plates were taken. The area included in 45^m of right ascension in the different zones of 1° in declination is :—

4·67	square	degrees	in zone	65°
4·48	,,	,,	,,	66°
4·31	,,	,,	,,	67°
4·12	,,	,,	,,	68°
3·94	,,	,,	,,	69°

The total number of stars found in the Bonn *Durchmusterung* for these areas and of the number of stars of the ninth magnitude, or brighter, are also included in the following table.

The table gives in parallel columns the stars shown in duplicate—*i.e.* on each of the overlapping plates—and the total number of stars shown with the various exposures.

TABLE I.

Number of Stars shown with Various Exposures for Areas of 1° *in Decl. and* 45^m *in R.A. in the Zones from* 65° *to* 70° *Decl.*

Limits of R.A.	Zone.	No. in B.D.		Number shown on Photographs.					
				Exposure 20ˢ.		Exposures 3^m and 6^m.		Exposure 40^m.	
		$9^{m}{\cdot}0$ and brighter.	Total No.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.
h m	°								
0 0 to 0 45	+65	44	108	53	95	181	264	1071	1390
	66	26	75	51	73	237	253	890	1138
	67	29	73	47	68	265	295	1336	1496
	68	17	60	50	78	282	308	1246	1394
	+69	17	48	40	90	302	373	1513	1680

Limits of R.A.	Zone.	No. in B.D.		Number shown on Photographs. Exposure 20°.		Exposures 3m and 6m.		Exposure
		9m·0 and brighter.	Total No.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.
h m	°							
0 45 to 1 30	+65	35	100	69	140	258	347	1073
	66	20	65	36	81	199	261	702
	67	21	66	25	39	140	165	1391
	68	31	71	47	71	239	306	2122
	+69	23	61	55	122	332	413	2792
1 30 to 2 15	+65	29	70	25	71	173	219	985
	66	22	69	36	61	176	218	837
	67	20	65	39	56	197	241	958
	68	16	49	43	59	277	317	1391
	+69	13	33	36	68	255	314	1799
2 15 to 3 0	+65	20	64	21	53	136	176	976
	66	12	37	13	19	62	68	720
	67	21	45	25	41	112	157	768
	68	27	54	57	96	198	323	887
	+69	21	54	68	130	361	420	1262
3 0 to 3 45	+65	23	46	36	75	147	193	527
	66	21	53	29	49	157	238	771
	67	18	49	31	51	188	307	1107
	68	18	78	45	85	250	305	1355
	+69	14	32	29	46	187	215	1287
3 45 to 4 30	+65	17	47	34	55	144	180	975
	66	14	64	30	33	150	166	1149
	67	19	45	29	52	158	249	1204
	68	18	51	26	58	147	200	1344
	+69	16	38	21	46	160	228	1127
4 30 to 5 15	+65	16	47	47	67	230	303	2306
	66	21	50	28	48	210	271	2530
	67	23	45	22	41	181	222	1964
	68	20	46	31	66	278	385	1620
	+69	29	51	56	83	361	425	1608
5 15 to 6 0	+65	19	46	48	80	270	338	2162
	66	14	37	26	63	201	340	1513
	67	11	30	26	46	181	260	1441
	68	13	39	43	72	321	448	1717
	+69	15	47	41	65	292	375	1748

Limits of R.A.	Zone.	No. in B.D.		Number shown on Photographs.					
				Exposure 20s.		Exposures 3m and 6m.		Exposure 40m.	
		9.0 and brighter.	Total No.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.
h m	°								
6 0 to 6 45	+65	18	33	48	63	254	299	1364	2164
	66	16	44	48	77	324	372	1172	1925
	67	13	45	33	57	250	355	1642	2115
	68	13	31	35	45	233	260	1737	1960
	+69	9	31	33	53	275	332	1655	1742
6 45 to 7 30	+65	8	34	25	43	172	206	1465	1929
	66	21	43	37	60	201	272	1166	1349
	67	21	41	32	61	250	411	1247	1523
	68	17	35	24	38	206	282	1452	1537
	+69	15	40	25	44	198	232	1235	1435
7 30 to 8 15	+65	17	45	36	61	204	257	1155	1395
	66	17	32	30	58	219	258	1153	1467
	67	14	37	30	52	243	301	1050	1425
	68	12	39	32	57	196	259	976	1253
	+69	17	34	20	37	169	206	1176	1370
8 15 to 9 0	+65	24	60	48	87	219	271	717	799
	66	15	53	40	68	214	263	912	1048
	67	13	28	25	48	168	233	873	1005
	68	13	26	22	38	167	184	891	984
	+69	10	43	38	59	206	271	989	1028
9 0 to 9 45	+65	16	54	21	36	130	157	773	901
	66	16	38	27	43	113	145	734	936
	67	23	44	38	49	145	164	747	952
	68	5	26	23	35	155	169	736	790
	+69	16	38	28	47	170	207	693	813
9 45 to 10 30	+65	17	47	37	52	160	192	749	868
	66	13	39	26	39	166	180	850	986
	67	17	40	29	40	150	170	750	921
	68	12	32	19	33	138	170	725	819
	+69	14	31	26	57	144	205	828	970
10 30 to 11 15	+65	17	42	45	65	202	248	684	771
	66	22	43	48	65	196	235	868	932
	67	11	26	27	38	135	169	830	888
	68	9	28	31	37	152	172	802	836
	+69	6	22	20	45	173	215	860	928

Limits of R.A.	Zone.	No. in B.D.		Number shown on Photographs. Exposure 20s.		Exposures 3m and 6m.		Exposure
		9m·0 and brighter.	Total No.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.
h m	°							
11 15 to 12 0	+65	13	38	25	41	131	151	757
	66	12	30	19	43	153	250	805
	67	20	34	37	58	209	249	738
	68	16	33	39	51	215	249	724
	+69	19	37	47	89	249	346	812
12 0 to 12 45	+65	21	40	28	44	128	173	682
	66	11	24	17	24	101	136	733
	67	9	35	22	38	137	187	686
	68	7	20	22	41	163	198	688
	+69	18	38	40	73	217	291	816
12 45 to 13 30	+65	17	38	33	57	156	191	801
	66	11	34	30	46	146	170	752
	67	11	24	19	29	137	165	754
	68	16	34	29	48	189	219	685
	+69	10	24	34	62	244	303	732
13 30 to 14 15	+65	20	42	36	52	154	173	640
	66	15	32	30	41	172	198	695
	67	20	46	33	42	164	210	775
	68	17	44	34	53	195	242	723
	+69	16	32	39	57	202	279	646
14 15 to 15 0	+65	25	52	38	59	141	208	831
	66	15	40	36	66	204	254	808
	67	14	34	31	49	189	236	768
	68	8	37	20	50	141	245	641
	+69	18	41	28	75	134	283	672
15 0 to 15 45	+65	12	42	31	87	166	255	972
	66	25	39	39	86	212	330	1024
	67	19	42	46	54	238	286	949
	68	13	37	29	59	210	251	685
	+69	16	33	38	63	215	273	742
15 45 to 16 30	+65	26	49	49	76	175	245	1201
	66	14	38	43	75	233	290	1107
	67	13	29	44	67	259	333	1112
	68	16	29	37	64	268	308	999
	+69	16	36	42	66	252	295	906

Limits of R.A.	Zone.	No. in B.D.		Number shown on Photographs. Exposure 20s.		Exposures 3m and 6m.		Exposure 40m.	
		9m·0 and brighter.	Total No.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.	Shown in duplicate.	Total No. of Stars.
h m	°								
16 30 to 17 15	+65	14	48	34	69	202	279	1190	1284
	66	19	52	53	81	251	317	1177	1287
	67	24	52	57	76	240	273	1368	1454
	68	18	43	37	65	259	301	1296	1338
	+69	23	51	62	90	247	316	1111	1209
17 15 to 18 0	+65	16	59	78	107	291	398	1408	1527
	66	18	62	54	82	301	367	1537	1935
	67	23	44	59	72	341	382	1839	1977
	68	24	48	64	93	372	397	1487	1548
	+69	23	61	68	111	338	392	1517	1546
18 0 to 18 45	+65	30	61	58	83	281	315	1697	2010
	66	18	58	72	94	316	403	1665	1744
	67	18	49	60	85	340	411	1359	1438
	68	18	51	46	87	310	446	1557	1753
	+69	15	37	50	89	346	469	1832	2051
18 45 to 19 30	+65	28	68	71	101	370	471	2170	2389
	66	24	84	85	121	442	545	2307	2441
	67	17	67	40	63	343	435	2249	2420
	68	17	51	57	102	406	479	2439	2534
	+69	17	51	97	131	538	608	1756	1868
19 30 to 20 15	+65	24	70	45	68	256	352	1979	2146
	66	27	72	37	69	256	390	1941	2022
	67	26	74	53	74	215	320	1300	1431
	68	15	49	41	58	290	326	1206	1296
	+69	16	42	43	56	237	253	1063	1162
20 15 to 21 0	+65	18	82	69	90	325	408	1792	2107
	66	23	78	37	79	209	307	1720	1816
	67	17	48	35	50	183	245	1003	1044
	68	17	57	47	78	322	378	1351	1499
	+69	15	44	55	88	307	358	1384	1616
21 0 to 21 45	+65	59	122	103	185	483	634	1910	1993
	66	34	96	46	78	256	352	1592	1749
	67	25	70	34	67	295	431	1535	1601
	68	21	74	57	97	391	441	1570	1773
	+69	21	62	52	82	314	374	1607	1686

Limits of R.A. h m	Zone. °	No. in B.D. 9m·0 and brighter.	No. in B.D. Total No.	Number shown on Photographs. Exposure 20s. Shown in duplicate.	Exposure 20s. Total No. of Stars.	Exposures 3m and 6m. Shown in duplicate.	Exposures 3m and 6m. Total No. of Stars.	Exposure Shown in duplicate.
21 45 to 22 30	+65	40	126	68	146	388	673	1761
	66	34	93	94	177	563	888	2249
	67	35	102	89	143	614	914	3015
	68	22	62	78	123	553	654	3504
	+69	35	70	96	134	480	569	1763
22 30 to 23 15	+65	37	101	68	98	354	389	1521
	66	30	84	50	72	305	348	1605
	67	27	62	36	64	283	349	1284
	68	22	70	63	95	362	442	1312
	+69	15	47	43	98	345	443	1560
23 15 to 0 0	+65	42	119	46	70	228	274	1107
	66	32	84	47	84	268	420	947
	67	32	86	48	79	286	461	1146
	68	21	66	49	71	221	275	1168
	+69	19	54	48	79	348	462	2029
Totals ...		3,094	8,152	6,663	11,018	38,262	49,014	199.776 2
Number per square degree.		4·5	11·8	9·7	16·0	55·6	71·2	290·1 3
Ratio of Totals.		1	2·6	2·1	3·6	12·4	15·8	64·6

By taking the sums for the five zones the number of st obtained for each area of 5° in Decl., and 45m in R.A. be Decl. +65° and +70°. Each trapezium into which this t the sky is thus divided contains 21·52 square degrees.

Table II.

Number of Stars shown with various Exposures for Areas of 5° *in Decl and* 45m *in Right Ascension* (21·52 *square degrees*) *between* 65° *and* 70° :

Limits of R.A. h m	h m	Number in B.D. 9m·0 and brighter.	Number in B.D. Total No.	Number shown on Photographs. Exposure 20s. Shown in Duplicate.	Exposure 20s. Total No. of Stars.	Exposures 3m and 6m. Shown in Duplicate.	Exposures 3m and 6m. Total No. of Stars.	Exposur Shown in Duplicate.
0 0–	0 45	133	364	241	404	1267	1493	6056
0 45–	1 30	130	363	232	453	1168	1492	8080
1 30–	2 15	100	286	179	315	1078	1309	5970
2 15–	3 0	101	254	184	339	869	1144	4613

Limits of R.A.	Number in B.D.		Number shown on Photographs.					
			Exposure 20s.		Exposures 3m and 6m.		Exposure 40m.	
h m h m	9m·0 and brighter.	Total No.	Shown in Duplicate.	Total No. of Stars.	Shown in Duplicate.	Total No. of Stars.	Shown in Duplicate.	Total No. of Stars.
3 0- 3 45	94	258	170	306	929	1258	5047	6558
3 45- 4 30	84	245	140	244	759	1023	5799	6669
4 30- 5 15	109	239	184	305	1260	1606	10,028	12,209
5 15- 6 0	72	199	184	326	1265	1761	8581	11,181
6 0- 6 45	69	184	197	295	1336	1618	7570	9906
6 45- 7 30	82	193	143	246	1027	1403	6565	7773
7 30- 8 15	77	187	148	265	1031	1281	5510	6910
8 15- 9 0	75	210	173	300	974	1222	4382	4864
9 0- 9 45	76	200	137	210	713	842	3683	4391
9 45-10 30	73	189	137	221	758	917	3902	4564
10 30-11 15	65	161	171	250	858	1039	4044	4355
11 15-12 0	80	172	167	282	957	1245	3836	4231
12 0-12 45	66	157	129	220	746	985	3605	4006
12 45-13 30	65	154	145	242	872	1048	3724	4096
13 30-14 15	88	196	172	245	887	1102	3479	4032
14 15-15 0	80	204	153	299	809	1226	3720	4119
15 0-15 45	85	193	183	349	1041	1395	4372	4952
15 45-16 30	85	181	215	348	1187	1471	5325	5721
16 30-17 15	98	246	243	381	1199	1486	6142	6572
17 15-18 0	104	274	323	465	1643	1936	7788	8533
18 0-18 45	99	256	286	438	1593	2044	8110	8996
18 45-19 30	103	321	350	518	2099	2538	10,921	11,652
19 30-20 15	108	307	219	325	1254	1641	7489	8057
20 15-21 0	90	309	243	385	1346	1696	7250	8082
21 0-21 45	160	424	292	509	1739	2232	8214	8802
21 45-22 30	166	453	425	723	2598	3698	12,292	13,739
22 30-23 15	131	364	260	427	1649	1971	7282	8242
23 15- 0 0	146	409	238	383	1351	1892	6397	7812
Total ...	3094	8152	6663	11,018	38,262	49,014	199,776	229,426

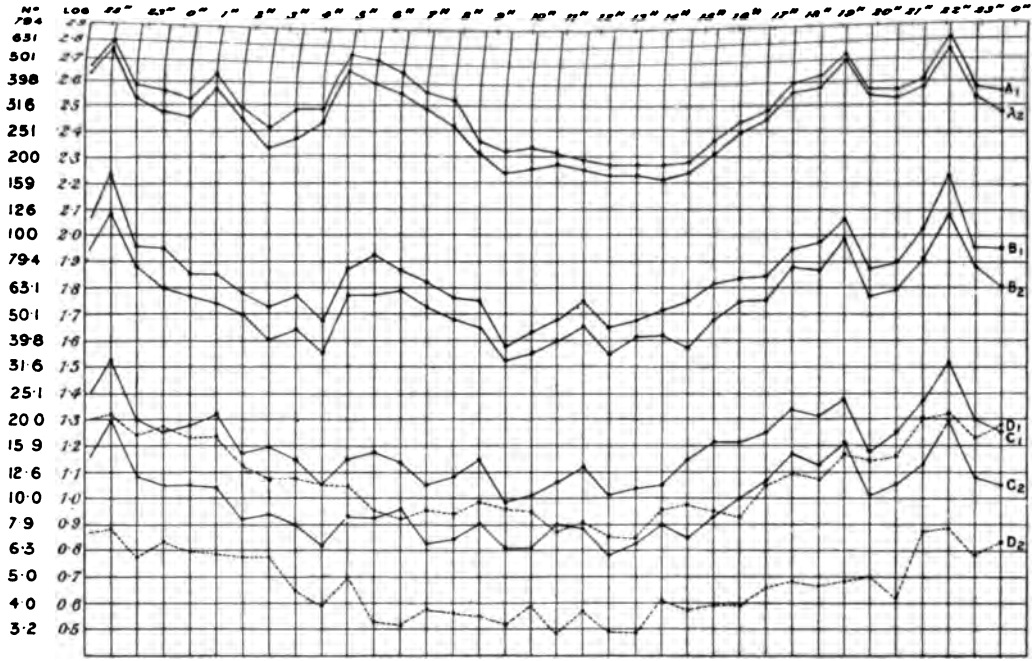
In Table III. the logarithms of these numbers are given, and in the diagram the logarithm of the number of stars per square degree is given, the numbers of the diagram being obtained from Table III. by subtracting logarithm 21·5 or 1·332.

TABLE III.

Logarithm of Number of Stars shown with Various Exposures for Areas of in Decl. and 45m in R.A. between the Limits +65° and +70° of Decl.

Limits of R.A.				Number in B.D.		Number shown on Photographs.					
						Exposure 20s.		Exposures 3m and 6m.		Exposure	
h	m	h	m	9m·0 and brighter.	Total No.	Shown in Duplicate.	Total No.	Shown in Duplicate.	Total No.	Shown in Duplicate.	
0	0–	0	45	2·124	2·561	2·382	2·606	3·103	3·174	3·782	3
0	45–	1	30	2·114	2·560	2·366	2·656	3·067	3·174	3·907	3
1	30–	2	15	2·000	2·456	2·253	2·498	3·033	3·117	3·776	3
2	15–	3	0	2·004	2·405	2·265	2·530	2·939	3·058	3·664	3
3	0–	3	45	1·973	2·412	2·230	2·486	2·968	3·100	3·703	3
3	45–	4	30	1·924	2·389	2·146	2·387	2·880	3·010	3·763	3
4	30–	5	15	2·037	2·378	2·265	2·484	3·100	3·206	4·001	4
5	15–	6	0	1·857	2·299	2·265	2·513	3·102	3·246	3·934	4
6	0–	6	45	1·839	2·265	2·294	2·470	3·126	3·209	3·879	3
6	45–	7	30	1·914	2·286	2·155	2·391	3·012	3·147	3·817	3
7	30–	8	15	1·887	2·272	2·170	2·423	3·013	3·107	3·741	3
8	15–	9	0	1·875	2·322	2·238	2·477	2·989	3·087	3·642	3
9	0–	9	45	1·881	2·301	2·137	2·322	2·853	2·925	3·566	3
9	45–	10	30	1·863	2·276	2·137	2·344	2·880	2·962	3·591	3
10	30–	11	15	1·813	2·207	2·233	2·398	2·933	3·017	3·607	3
11	15–	12	0	1·903	2·236	2·223	2·450	2·981	3·095	3·584	3
12	0–	12	45	1·819	2·196	2·111	2·342	2·873	2·993	3·557	3
12	45–	13	30	1·813	2·188	2·161	2·384	2·940	3·020	3·571	3
13	30–	14	15	1·945	2·292	2·235	2·389	2·948	3·042	3·541	3
14	15–	15	0	1·903	2·310	2·185	2·476	2·908	3·088	3·570	3
15	0–	15	45	1·929	2·286	2·262	2·543	3·017	3·145	3·641	3
15	45–	16	30	1·929	2·258	2·332	2·542	3·074	3·168	3·726	3
16	30–	17	15	1·991	2·391	2·386	2·581	3·079	3·172	3·788	3
17	15–	18	0	2·017	2·438	2·509	2·667	3·216	3·287	3·891	3
18	0–	18	45	1·996	2·408	2·456	2·641	3·202	3·310	3·909	3
18	45–	19	30	2·013	2·506	2·544	2·714	3·322	3·404	4·038	4
19	30–	20	15	2·033	2·487	2·340	2·512	3·098	3·215	3·874	3
20	15–	21	0	1·954	2·490	2·386	2·585	3·129	3·229	3·860	3
21	0–	21	45	2·204	2·627	2·465	2·707	3·240	3·349	3·914	3
21	45–	22	30	2·220	2·656	2·628	2·859	3·415	3·568	4·090	4
22	30–	23	15	2·117	2·561	2·415	2·630	3·217	3·295	3·862	3
23	15–	0	0	2·164	2·612	2·377	2·583	3·131	3·277	3·806	3
Mean ...				1·970	2·385	2·298	2·518	3·056	3·162	3·769	3

exposures, between 65° and 70° North Declination.



A, Total number of Stars shown with an exposure of 40m.
B, Total number of Stars shown with exposures of 3m & 6m.
C, Total number of Stars shown with an exposure of 20s.
D, Total number shown in Bonn Durchmusterung.

A$_2$ Number shown in duplicate, *i.e.*, on both of the overlapping places.
B$_2$ Number shown in duplicate, *i.e.*, on both of the overlapping places.
C$_2$ Number shown in duplicate, *i.e.*, on both of the overlapping places.
D$_2$ Number in B.D. of magnitude 9·0 and brighter.

Examination of the tables and diagram (Plate 7) shows the following results:—

(i.) The logarithm of the ratio of the greatest to the least number of stars per square degree is

0·54 or 0·55 for the 40^m exposure
0·56 or 0·64 for the 3^m and 6^m exposures
0·51 or 0·52 for the 20^s expesures
and 0·47 for the Bonn *Durchmusterung*.

where the first figure in each case is derived from the number of stars counted in duplicate and the second from the total number of stars. These figures show that the maximum number of stars per square degree rises to 3·5 times the minimum number for the 40^m exposure, about 4·0 times for the 3^m and 6^m exposures, and to about 3·2 times for the 20^s exposures.

(ii.) The numbers of the stars for the exposures 40^m, 6^m and 3^m, and 20^s maintain the same ratio for different parts of the sky. The only notable exception is the increase in the numbers of the 6^m and 3^m exposures, and more still of the 40^m exposures from 5^h to 6^h. This is not shown by the 20^s exposures.

(iii.) The variation in the number of stars per square degree given in the Bonn *Durchmusterung* is on the whole well supported by the short-exposure photographs. There is not in this region any marked falling off in the B.D. where the stars are rich, though there appears to be a slight deficiency at the maximum near 22^h. Relatively to the photographs the B.D. is rich in stars from 23^h to 5^h, and poor from 12^h to 19^h.

(iv.) Generally the number of stars shown with 20^s exposure is considerably in excess of the total number given in the Bonn *Durchmusterung*, while the number shown in duplicate (on both of the two overlapping plates) is generally less.

(v.) The ratio of the total number of stars shown to the number which are shown in duplicate on both overlapping plates is very constant for each of the three different series of exposures, but apparently differs from one to another. These ratios are :

Exposure.	Log. Ratio.	Ratio.
20^s	·220	1·66
3^m and 6^m	·106	1·28
40^m	·059	1·15

The cause of the smaller ratio for the 3^m and 6^m exposures is, as will be shown in the next paragraph, that the figures and diagrams given for the 6^m and 3^m exposures in the case of the "total number" of stars nearly correspond to the 3^m images, but do not for the number "shown in duplicate."

For the 40^m exposure the smallness of the ratio is probably due to the caution of the observers, who were instructed not to include any doubtful images seen only on one plate unless they were absolutely convinced that these were not photographic defects.

As it seemed of interest to obtain a formula givi number of stars per square degree in terms of the dura the exposure, a further analysis has been made of the n of stars shown with 3^m exposure for Zone 69°. These nu are given in the following table compared with the corresp numbers of Table I. The logarithms of their ratios ar given.

Number of Stars in Zone 69° shown with an Exposure of 3^m compared Number previously tabulated of those shown with 3^m and 6^m Expos

Limits of R.A.				Total Number. Exposure		Log. Ratio.	Number. Exposure	
h	m	h	m	3^m or 6^m.	3^m.		3^m or 6^m.	3^m.
0	0–	0	45	373	347	·031	302	199
0	45–	1	30	413	399	·015	332	226
1	30–	2	15	314	304	·014	255	186
2	15–	3	0	420	408	·012	361	277
3	0–	3	45	215	208	·014	187	152
3	45–	4	30	228	217	·022	160	96
4	30–	5	15	425	391	·036	361	250
5	15–	6	0	375	360	·018	292	220
6	0–	6	45	332	323	·012	275	199
6	45–	7	30	232	227	·009	198	148
7	30–	8	15	206	204	·004	169	137
8	15–	9	0	271	268	·005	206	163
9	0–	9	45	207	200	·015	170	118
9	45–	10	30	205	201	·009	144	96
10	30–	11	15	215	212	·006	173	122
11	15–	12	0	346	341	·006	249	207
12	0–	12	45	291	283	·012	217	174
12	45–	13	30	303	297	·009	244	190
13	30–	14	15	279	275	·006	202	138
14	15–	15	0	283	282	·002	134	105
15	0–	15	45	273	268	·008	215	158
15	45–	16	30	295	290	·008	252	209
16	30–	17	15	316	312	·006	247	209
17	15–	18	0	392	379	·014	338	266
18	0–	18	45	469	463	·005	346	281
18	45–	19	30	608	592	·012	538	419
19	30–	20	15	253	248	·009	237	172
20	15–	21	0	358	346	·015	307	231
21	0–	21	45	374	356	·022	314	221
21	45–	22	30	569	551	·014	480	392
22	30–	23	15	443	438	·005	345	261
23	15–	0	0	462	456	·006	348	264
					Mean	·012		

The above table shows that the total number of stars which give images with 3^m exposure on one of the two plates for each area is only very slightly less than the total number given in Tables I., II., III., and in the diagram as corresponding to an exposure of 3^m or 6^m, the difference ·012 of the logs. corresponding to a ratio of 0·97 to 1. This is due to the method adopted in the measurement of rejecting single images seen only on one plate (see p. 121). There is, however, a very considerable difference in the number of stars shown on both plates with an exposure of 3^m and the corresponding numbers tabulated above for 3^m and 6^m; the difference of ·126 in the logarithms corresponding to a ratio of ·75 to 1·00.

Assuming that these figures, which are actually found only for Zone 69°, apply to the five zones, we have for the logarithms of the number of stars per square degree with the different exposures—

I. *Shown on both Plates.*

20^s.	3^m.	6^m.	40^m.
0·966	1·598	1·724	2·437.

II. *Total Number shown.*

20^s.	3^m.	6^m.	40^m.
1·186	1·818	1·830	2·496

It would seem that these numbers are accurate in the first case, but that in the second case not all the stars shown with 6^m exposure are counted, and probably not all of those shown with an exposure of 40^m. The difference of the logarithms of the number of stars shown with an exposure of 3^m and with an exposure of 20^s is ·632 both for the number of stars shown in duplicate and for the total number, while the difference for the exposures 40^m and 20^s is 1·471 for the stars shown in duplicate and 1·310 for the total number. Assuming the formula $\log \frac{N}{N_o} = k \log \frac{T}{T_o}$, where N is the number of stars per square degree shown with duration of exposure T, the interval 20^s to 3^m gives $k = ·66$, and the interval 20^s to 40^m gives $k = ·70$ for stars shown in duplicate and ·63 for the total number. Thus we may take $\log \frac{N}{N_o} = ·67 \log \frac{T}{T_o}$ or $\left(\frac{N}{N_o}\right)^2 = \left(\frac{T}{T_o}\right)^3$ as a good approximate formula for the increase of numbers with exposure between the limits of 20^s and 40^m.

On the assumption that an equal total amount of light produces an equal photographic effect, an additional magnitude is reached by increasing the exposure 2·5 times. Between the 3^m and 20^s (ratio of 9 to 1) there corresponds a difference of magnitude $2^m·36$. Between the 40^m and 20^s exposure (ratio 120 to 1) there is a difference of $5^m·20$. If r be the ratio of the

number of stars down to magnitude $m + 1$ to the number down to magnitude m, we obtain

$$r^{s\cdot 38} = 4\cdot 29 \text{ [log} = \cdot 632\text{] from the } 20^s \text{ and } 3^m \text{ images}$$
$$r^{s\cdot 20} = 29\cdot 58 \text{ [log} = 1\cdot 471\text{] from the } 20^s \text{ and } 40^m \text{ images}$$

Thus from the 20^s and 3^m images we get $r = 1\cdot 84$
and from the 20^s and 40^m images we get $r = 1\cdot 92$

These ratios are deduced from the number of stars shown in duplicate.

The variation of the star density with the distance from the Milky Way is distinctly shown, though not in very striking manner by these counts, as the area considered only just reaches the Milky Way at about 0^h, and is 50° from it at 12^h. The minimum number of stars per square degree, especially for the 40^m exposure, is very noticeable from 9^h to 15^h. Here the distance from the Milky Way lies between 50° to 43°. There is a gradual rise to about three times this number of stars at 5^h and 19^h, when the centre of the zone considered approaches closely to the Milky Way, and there is a still more pronounced maximum at 22^h, which is strikingly shown with all three exposures. Between 19^h and 5^h, where the zone approaches and just enters the galaxy, there are, as the diagram shows, some irregularities with two maxima and three minima.

Note on the Reproduction and Publication of the Photographs for the Astrographic Chart taken at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

In accordance with the recommendation of the International Committee, it is proposed to reproduce and distribute to a limited number of Observatories and Institutions the Greenwich portion of the Astrographic Chart, the original negatives being enlarged to twice the scale.

After careful trial a method of direct photographic reproduction has been adopted, prints being taken by contact on bromide card (15 in. × 12 in.) from an enlarged positive on glass. By this method it is found that practically no stars are lost in reproduction, and that there is little liability to the introduction of false stars in the process beyond those which may exist in the original negative, and these can readily be detected by reference to the overlapping plate. They are for the

it part large and round, and can be as readily distinguished h a single image as with a triple image, which for such e stars is practically blended into one.

On full consideration it is believed that sufficient provision be made for the utilisation of the Astrographic Chart if the oduction is limited to fifty sets, to be distributed to a selected of Observatories and Institutions (including the eighteen icipating Observatories) where proper provision is likely to made for the satisfactory storage of the 22,000 sheets of ch the chart will consist ; an important consideration in view he bulky nature of the work. It is to be noted that itional sets can be taken subsequently to meet any further and which may arise.

A careful estimate gives for the cost of reproduction of fifty of the 1,149 plates of the Greenwich Zone, including the paration of two sets of positive enlargements on glass, 3,000*l.*, it the rate of 60*l.* a set—equivalent to one shilling per print on mide card 15 in. × 12 in. This is the total cost of labour, tes, paper, and chemicals. It is estimated that two persons rking together can complete the fifty sets for the Greenwich ne (about 2,400 positive enlargements and 60,000 bromide nts, 15 in. × 12 in.) in from five to six years.

The following method has been adopted as the result of periments on purely photographic lines. From the original irt plate a positive on glass of twice the scale is made in a mera using a lens working at $f/8$ and with a focal length 11·2 inches. A uniform illumination is obtained by the egularly reflected light of a white screen, illuminated by ctric lamps arranged symmetrically round the plate.

From this positive, prints on glazed bromide paper are made contact. The paper employed is a thin card, the sheets being inches by 12. This gives a half-inch margin at the sides l about 2 inches at the top and bottom, thus leaving room the insertion of title and data concerning the plate.

The prints obtained by this process are exact copies of the ginal, and no retouching is effected to eliminate any defects ich might be mistaken for stars. Generally there is no iculty, but in all cases of doubt reference to the same field on overlapping plate can be made. Counts were made of the mber of stars shown on the original negatives and on the nts for three pairs of overlapping plates, and 1,046 images re found on the prints and 1,060 on the original plates. It us appears that practically all stars shown on the plates are produced on the prints.

Note on Photographs of Comet d 1902 *Giacobini obtained wi 30-inch Reflector at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

Seven photographs of this comet have been obtained the 30-inch reflector on six nights, with exposures varying thirty minutes to five minutes. In the case of three photo the driving of the telescope was corrected to allow for the c motion, but the remaining photos were taken with the tel guided on the stars, the comet's motion in ten minutes being small. The comet is well shown with an exposure of ten mi the photographic image being of stellar character, and capa very exact measurement.

The following is a list of the photographs obtained up present time :—

Date.	Exposure.	Remarks.
1902.		
Dec. 29	30m	Comet's motion in R.A. and Decl. cor
„ 30	10m, 15m	Comet's motion in Decl. corrected.
„ 31	10m, 7½m, 10m, 5m	„ „
1903.		
Jan. 2	10m, 10m, 8m	Telescope guided on the stars.
„ 3	10m, 10m, 10m	„ „
„ 7	15m	„ „
„ 7	15m	„ „
„ 8	10m, 10m	„ „

Royal Observatory, Greenwich:
1903 *January* 9.

Note on Plate Constants. By F. W. Dyson, M.A., F.R.

In a paper by the Astronomer Royal and myself (*Mo Notices*, vol. lvi. pp. 114–134) the reduction of a numb astrographic plates according to the formulæ and methods by Professor Turner (*Monthly Notices*, vol. liv.) was consid It was shown that the constants a and e computed in this gave discordances with the values of these constants calcu so as to correct for the scale of the telescope, and for the d ential effects of aberration and refraction of a magnitude might be expected from the errors of the right ascension declinations of the reference stars. Similarly the cons b and d, which are mainly caused by an orientation error o plate, showed differences of the magnitude which would from the errors of the reference stars. It was considered, t fore, that it would be better to use calculated values of a a

lue of the orientation error from the mean of the *b* and s, and thus use the data of the plate to furnish only nstants—namely, the orientation and the errors of the f the plate in the two directions. This was a modification sor Turner's method, in which six independent constants ived from the data of the plate itself. The grounds for of six constants are that these will tend to correct ible errors of distortion, whether optical or arising he drying of the gelatine, tilt of the plate, &c. The on which was arrived at by the Astronomer Royal and ras that the uncertainties of the position of the reference re sufficient to account for the differences of the plate s from their theoretical values.

six plate constants have been computed by Professor s method for 508 of the Greenwich astrographic plates. For ese the right ascensions and declinations of the Helsingfors ristiania Catalogues have been used. These stars are observed at Greenwich; and, although not more than two tions have been generally obtained, it seemed of interest pute with the positions of the reference stars the plate ts for those plates which showed the greatest dis-es.

following table gives the results of the two determina-he unit being in the fifth decimal place, *i.e.* −99 is 9, &c.) :—

TABLE I.

Plate Constants.

	Old Determination.				New Determination.			
	a.	*c.*	*b.*	*d.*	*a*	*c.*	*b.*	*d.*
	− 57	− 41	+133	−180	− 85	− 65	+166	−159
	− 48	−110	+296	−306	− 61	− 66	+279	−314
	− 6	− 57	+281	−320	− 56	− 79	+305	−282
	− 53	−126	+105	−108	− 68	− 80	+101	−124
	− 27	− 90	+ 80	− 66	− 60	− 71	+ 75	− 69
	− 99	− 68	+120	−190	− 57	− 76	+137	−158
	− 96	− 40	+407	−428	− 87	− 74	+373	−414
	− 77	−137	−107	+129	− 92	− 81	−109	+138
	− 95	− 77	+ 36	− 98	− 99	− 77	+ 40	− 65
	− 54	− 32	+ 45	− 10	− 59	− 46	+ 20	− 4
	−103	− 37	+122	−130	−105	− 95	+138	−159
	− 30	− 85	+102	−105	− 55	− 85	+102	−106
	− 66	− 82	+220	−282	− 78	− 81	+235	−244
	− 74	− 77	+242	− 308	− 70	− 76	+293	−300
	− 35	−113	+370	−338	− 76	− 66	+373	−371
	− 57	− 33	+294	−303	− 67	− 63	+309	−332
	− 67	− 28	+ 77	− 71	− 78	− 76	+ 19	− 31

It will be seen that all the large discordances in the values of a and e, whose theoretical value is about -00070 (varying principally owing to aberration from -00064 to -00076) are removed.

The discordances between the plate constants are so much diminished by improved right ascensions and declinations of the reference stars that it seems reasonable to look upon the uncertainties in the positions of these stars as the main source of error, and to conclude that any real variations of the constants due to distortion, &c., are less than the accidental errors of their determination. This is at any rate the case unless the reference stars are extremely well observed; and less error will be introduced by neglecting the small possible effects of distortion, tilt, &c., than by introducing the accidental errors which are involved in the determination of three additional constants.

The large difference in the values of b and d in the last plate, in addition to the change in the value of e, made it of interest to compute the final residuals with the adopted constants $a = e = -\cdot00075$ $b = -d = +25$. The following table gives the right ascensions originally used, the right ascensions and declinations from recent Greenwich observations, and the differences between Greenwich and Christiania, and between the Greenwich meridian observations and the photographs. The numbers in the third column give the number of observations at Greenwich.

TABLE II.

(*Assumed right ascensions and declinations of reference stars on Plate 4807 in the first and second determinations of plate constants, and the final residuals with the adopted constants* $a = e = -\cdot00075$ $b = -d = +\cdot00025$.)

No. in Chr. Cat.	Position from Greenwich Observations. R.A.		Decl.		No. of Obs.	Corrections to Christiania. R.A.		Decl.	Final Residuals on Photo. R.A.	Decl.
	h m s		° ′ ″			s	″	″	″	″
1567	9 57 51·93		68 4 37·4		3	−·01	= −0·0	+2·1	+0·5	−04
51	49 12 97		14 12·5		2	+·13	+0·7	+2·2	+0·5	+0·2
66	57 34·62		23 5·8		2	−·07	−0·6	+0·3	−0·5	−1·1
41	45 30·49		38 14·5		2	+·38	+2·1	−0·2	−0·7	+0·4
32	39 11·82		56 50·1		2	−·14	−0·7	+0·5	−0·5	+0·7
52	49 18·74		57 19·3		2	−·08	−0·4	−2·0	+0·3	+0·4
79	10 1 33·70		59 9·8		1	−·11	−0·6	+1·2	+1·2	−0·3
68	9 58 23·15		69 8 57·9		2	−·07	−0·4	+1·5	+0·3	0·0
56	53 28·74		11 52·4		3	−·08	−0·5	−0·1	+0·3	−0·1
77	10 0 56·22		11 29·9		2	−·21	−1·1	+0·8	−0·7	−0·2
80	1 37·80		9 13·9		1	−·20	−1·1	−0·2	−1·4	−0·2
59	9 54 53·81		16 3·3		3	−·34	−1·7	+1·0	−0·6	+1·2
44	46 47·25		24 42·8		1	−·45	−2·4	0·0	0·0	−0·4
45	46 49·08		24 42·6		1	−·58	−3·0	−1·2	+0·5	−0·2

Position from Greenwich Observations. R.A.	Decl.	No. of Obs.	Corrections to Christiania. R.A.	Decl.	Final Residuals on Photo. R.A.	Decl.
h m s	° ′ ″		s	″ ′ ″	″	″
46 49·97	22 21·1	5	+·02	+0·1 −1·5	+0·8	+0·1
48 47·58	22 28·0	2	+·20	+1·1 −0·2	−0·4	−0·6
54 20·45	31 16·3	4	−·27	−1·4 +0·6	−0·1	+0·1
46 8·34	55 21·7	1	−·61	−4·2 −4·0	+0·5	−0·8

aking this plate, which was chosen quite at random, as r sample of the results which will be given by the rwich astrographic work, the smallness of the residuals remely satisfactory.

a R.A. the mean discordance is $\pm$·0018 = $\pm$0″·54
a Decl. „ „ „ „ $\pm$·0014 = $\pm$0″·41

he corresponding probable errors are $\pm$0″·46 and $\pm$0″·35.

a the introduction to the Greenwich Catalogue for 1890 the able accidental error of an observation of right ascension is n as $\pm$ˢ·033 (= $\pm$″·50), and between the limits of Decl. of Greenwich Zone the probable accidental error of an observa- of Decl. is $\pm$0″·46. Each of the reference stars on this has been observed about twice, so that the resulting R.A. Decl. may be expected to have probable errors of about ·35 and $\pm$0″·32.

Comparing these with the figures $\pm$0″·46 and $\pm$0″·35, it is that the errors of the photographic results are extremely l.

The above table, as well as Table I., shows the advantage h has resulted from the re-observation of the reference stars the transit circle. With five observations of each reference it would seem the uncertainties of the plate constants, h are the principal source of the error in the deduction .A. and Decl. from the astrographic photographs, will be iently reduced.

Returning now to the computation of the plate constants, e is a considerable simplification of the work when a and e known beforehand. The quantities $x - ax$ are tabulated in r of y and equated to $by + c$. The solution of these equa- , which should be done by least squares with approximate hts when the number of stars is small or when the stars are y distributed, gives b and c. Similarly the quantities $y - ey$ are nged in order of x and equated to $dx + f$, and the equations d for d and f. The mean of b and $-d$, with a possible ction of ·00001 when the plate is taken one hour from the dian, is adopted. The advantage of the arrangement in r of y and x is that any mistakes which may have been looked are likely to be detected before the equations are d.

A Graphical Method of Applying to Photographic Measures the Terms of the Second Order in the Differential Refraction.

Arthur R. Hinks, M.A.

1. The great and well-known advantage of Turner's methods of reducing in rectangular coordinates the measures made upon a photograph depends upon the fact that all the various small differences, due to refraction, aberration, orientation, centering, &c., by which the measures of stars on an actual plate differ from what they would be on an ideal "standard" plate are usually linear functions of the coordinates, and their value can be deduced *en bloc* by comparing the measured coordinates of known stars with their computed coordinates on the ideal plate. So soon as any of the corrections necessary begin to involve terms of the second order in x and y, the measured coordinates, the simplicity of the method is lost, but may be restored by finding separately and applying to the measures such parts of the whole reductions as are of the second order in x and y; when this is done the main part of the reduction proceeds as before.

2. The only parts of the reductions which are likely to involve second-order terms are the differential refractions. In the reduction of the photographs of *Eros*, many of which were necessarily taken at considerable zenith distances, these terms occasionally amount to one- or two-tenths of a second of arc; it is therefore necessary to take account of them before proceeding to form the equations and make the solution for the ordinary six constant reductions. But since nothing is more aggravating than having to compute for each star a number of small quantities which when added together amount generally to not more than one or two units in the last place of decimals employed, I tried various ways of computing these small terms graphically, and have succeeded in constructing three diagrams by means of which the second-order refraction terms can be found in a few minutes for any plate taken anywhere in the world. It seems possible, then, that these diagrams may be found of general use.

3. The expressions for the complete effect of refraction have been given by Professor Turner (*Monthly Notices*, lvii. 1897, p. 133). It is there shown that if (x, y) be the coordinates of an unrefracted star, and β the constant of refraction, the effect of refraction is to displace the star image on the plate to the point whose coordinates are

$$x+t(\mathrm{X}-x),\ y+t(\mathrm{Y}-y)$$

where

$$t=\beta\,\frac{1+x^2+y^2}{1+x\mathrm{X}+y\mathrm{Y}+\beta\{x(x-\mathrm{X})+y(y-\mathrm{Y})\}}$$

and X, Y are the coordinates of the projection on the plate of the zenith. It is further shown that the term in β in the denominator may be neglected.

If we expand the above expressions the whole refractions Δx, Δy are given by

$$\Delta x/\beta = X - x(1+X^2) - yXY + x^2X(2+X^2) + xyY(1+2X^2) + y^2X(1+Y^2)$$
$$\Delta y/\beta = Y - xXY - y(1+Y^2) + x^2Y(1+X^2) + xyX(1+2Y^2) + y^2Y(2+Y^2)$$

where the square of β and the cubes of x and y are neglected.

[It should be noted that Professor Turner has inadvertently omitted in his paper these general expressions. Those given on p. 136 are for the particular case $Y = 0$.]

The terms in the first line of each expression are the terms that are included in the ordinary reductions implicitly, together with the other linear expression for the corrections for aberration, &c. The second-order terms, in the second line, are those which I shall propose to find by a graphical method.

4. Suppose $X = 0$; that is, the plate is taken on the meridian.

Then $Y = \tan$ (zenith distance of centre)
$= Z$ suppose

and $\Delta x/\beta = Z \cdot xy$
$\Delta y/\beta = Z \cdot x^2 + Z(2+Z^2) \cdot y^2$

In this particular case the axis of y, the north and south line on the plate, is also the projection of the vertical great circle through the centre of the plate; and it is clear that if we take a plate in any hour-angle, with centre at zenith distance $\tan^{-1}(Z)$, and refer our stars to rectangular axes of h, k, of which the axis of k is the projection of the vertical, then

$$\Delta h/\beta = Z \cdot hk$$
$$\Delta k/\beta = Z \cdot h^2 + Z(2+Z^2) \cdot k^2$$

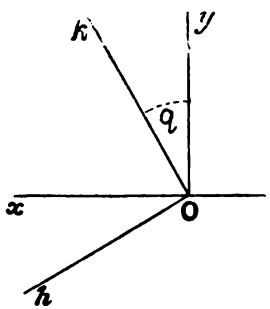


FIG 1.

We have now two sets of axes on the plate; Ox, Oy the axes of measurement of which the positive direction of Ox is towards increasing right ascension, the positive direction of Oy northwards; Oh, Ok, the new axes, of which Ok is the projection of the vertical, with positive direction towards the zenith, Oh at right angles to this, and positive towards the east.

The angle kOy is the parallactic angle at the point corresponding to the centre of the plate, and according to the usual convention increases positively as the hour-angle increases westward of the meridian—that is, as Ok swings round from positive Oy towards positive Ox.

Consequently the displacements in x and y, due to the second-order terms of the differential refraction, are

$$\Delta x/\beta = Zh^2 \sin q + Zhk \cos q + Z(2+Z^2)k^2 \sin q$$
$$\Delta y/\beta = Zh^2 \cos q - Zhk \sin q + Z(2+Z^2)k^2 \cos q$$

All the points on the plate for which the *displacement* in x is a quantity c (the *correction* $-c$) lie on the conic

$$c/\beta = Zh^2 \sin q + Zhk \cos q + Z(2+Z^2)k^2 \sin q,$$

which is at present referred to the axes of h, k. And a similar equation gives the locus of a given displacement in y.

5. To draw these curves we must refer them to their principal axes. Let Ou, Ov be the principal axes of the Δx conic; let Ov make an angle ϕ with the axis Ok, increasing in the same sense as the angle q.

Then, remembering that $Z \sin q = X$; $Z \cos q = Y$ we easily find that

$$\cot 2\phi = X(1 + X^2 + Y^2)/Y$$

and after considerable reduction the equation of the conic is found to be

$$(X - \tfrac{1}{2} Y \tan \phi)\, u^2 + (X + \tfrac{1}{2} Y \cot \phi)\, v^2 = c/\beta$$

If then a, b are the semi-axes of the conic

$$b = \left\{ \frac{c}{\beta (X + \tfrac{1}{2} Y \cot \phi)} \right\}^{\frac{1}{2}}; \quad \frac{a}{b} = \left\{ \frac{X + \tfrac{1}{2} Y \cot \phi}{X - \tfrac{1}{2} Y \tan \phi} \right\}^{\frac{1}{2}}$$

6. And similarly it may be shown that the locus of points where the *displacement* in y is c (and consequent *correction* $-c$) is a conic for which

$$b' = \left\{ \frac{c}{\beta (Y - \tfrac{1}{2} X \cot \phi')} \right\}^{\frac{1}{2}}; \quad \frac{a'}{b'} = \left\{ \frac{Y - \tfrac{1}{2} X \cot \phi'}{Y + \tfrac{1}{2} X \tan \phi'} \right\}^{\frac{1}{2}}$$

where $\cot 2\phi' = -Y(1 + X^2 + Y^2)/X$.

7. Now suppose that we had a diagram or a table of double entry, with arguments X, Y, from which to find ϕ; and that

we had found ϕ for certain values $X = m$, $Y = n$. It is clear that if we had taken $X = n$, $Y = m$, we should have found the value of $-\phi'$ instead of ϕ; and the same table or diagram will give us the values both of ϕ and of ϕ'.

Further, if we had a table or diagram to give us the value b when X and Y are known, and had found b for $X = m$, $= n$; substituting instead $X = n$, $Y = m$, we should have found b' instead of b; and the same table or diagram will give b and b' by an interchange of the values we assign to the arguments X and Y.

A similar interchange of arguments gives us either a/b or a/b' from the same diagram.

Again, in a table which gives q with arguments X and Y, interchange of the values of the arguments gives us $\frac{\pi}{2} - q$ instead of q. And we have seen that in a table for ϕ interchange of the arguments gives us $-\phi'$. Hence in a table for $q + \phi$, interchange of the arguments gives us $\frac{\pi}{2} - (q + \phi')$, and a table of $\frac{\tan}{\cot}(q + \phi)$ will give us by interchange of the arguments $\frac{\cot}{\tan}(q + \phi')$. It follows that we need only three diagrams, for b, a/b, and $(q + \phi)$, all with double arguments X and Y, to enable us to draw both the Δx and the Δy conics.

8. Consider now the first of the Δx conics. It is to be the boundary line on the plate between the regions for which Δx is respectively 0 and 1 in the last place of decimals which we propose to use in our reductions, and the question arises, What shall we take as the unit of our measures in diagrams which may, it is hoped, be of general use? Were there no uniformity at all in the focal lengths of photographic telescopes, there could be, I imagine, no doubt that the most convenient unit in which to *publish* measures (not to make them) would be the focal length of the telescope, or some decimal part of it. The fact that there is actually considerable uniformity, due to the adoption of a standard pattern for the telescopes which are making the astrographic chart, and which give a scale $1' = 1$ mm., might suggest that it would be better to adopt as the unit either a minute of arc or five times that quantity, the astrographic réseau interval. Inasmuch, however, as there is no uniformity in the practice of the Observatories which are making the chart and catalogue, since some publish their measures in minutes of arc and some in réseau intervals; further, since it is necessary to go to four places of decimals in either case, though the ten-thousandth of $5'$ is rather too large, and the ten-thousandth of $1'$ decidedly too small to bear its proper proportion to the actual uncertainty of the last figure retained; and, finally, since in the Eros reductions which we have undertaken at Cambridge a considerable proportion of the measures, made in millimetres, on plates from Lick, Northfield, Minneapolis, and Cambridge,

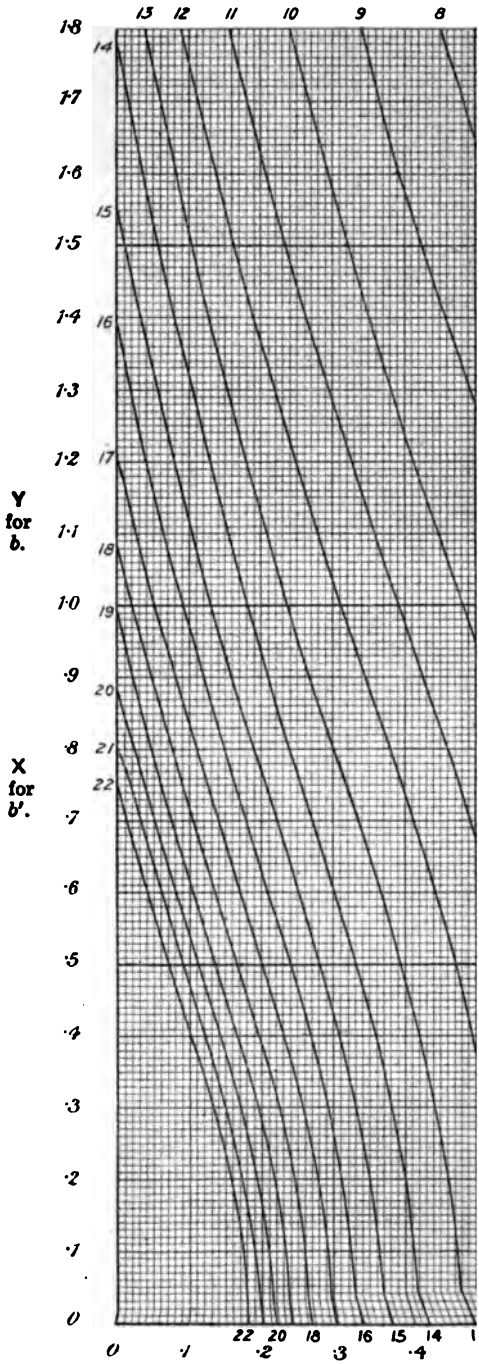


DIAGRAM I.

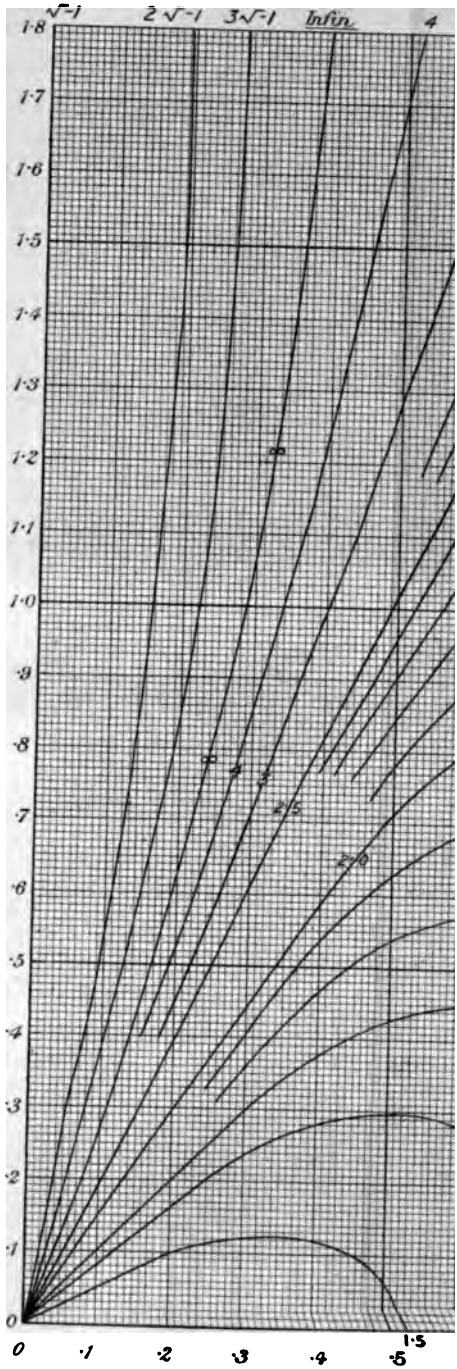
b and b'.

he sign of the
ction is + or −
rding as X for b
Y for b'
or +.

and b' are given
his diagram in
andths of the
length. If it is
red to express
in terms of
ner unit whose
to the focal
h is μ, the
s found here
be multiplied
$(1000\ \mu)^{-\frac{1}{2}}$.

DIAGRAM II.

a/b and a'/b'.



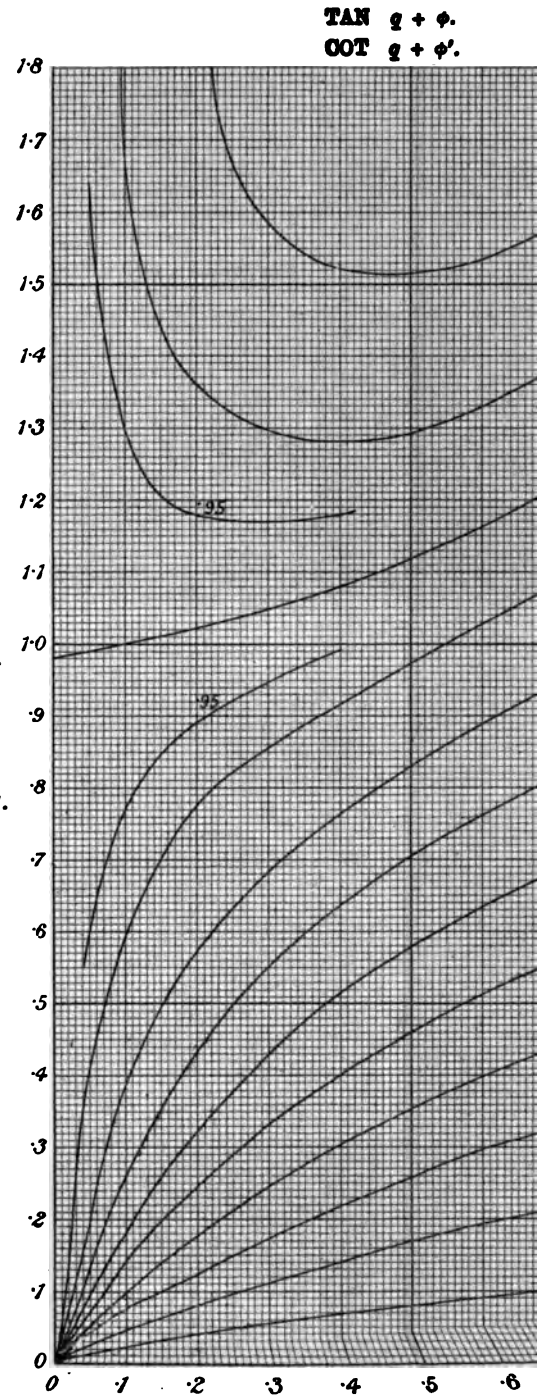
Y for a/b.

X for a'/b'.

DIAGRAM III.

TAN
COT $q+\phi, q+\phi'$.

If X and Y are of
ne sign, quantities
n this diagram
+ ve; if X and
re of opposite
quantities are
l.



than 45°, and with these quantities the axes of the conics may be laid down on squared paper without trouble.

11. In by far the greater proportion of cases the Δx and Δy conics are both ellipses. If either X or Y is small, one or the other of them will generally be an hyperbola ; but its semi-axes will usually be so large that it will lie altogether off the plate diagram, and we will postpone for a little the treatment of the few cases when the conic is an hyperbola and comes on to our plate diagram.

Consider a case where the first Δx conic is an ellipse, semi-minor axis b. This ellipse is the boundary between the regions on the plate where the second-order refraction correction Δx is respectively 0 and 1 in the fourth place of decimals ; or it is the locus of points where the correction is ·00005. The boundary between the zones of correction 1 and 2 will be a similar conic whose semi-axes are $\sqrt{3}$ times those of the first, and whose axes are in the same ratio. Similarly, between the zones of correction 2 and 3 the boundary is a conic with axes $\sqrt{5}$ times those of the first, and so on.

Now if we had to draw all these ellipses the method would be valueless in practice—at least, until someone shall invent an ellipsograph to draw ellipses of a required size and shape without troublesome adjustments. But, fortunately, all that is necessary is to draw the auxiliary circles upon the minor axes ; that is to say, having given b for the first ellipse, to draw a series of concentric circles with radii b, $\sqrt{3}b$, $\sqrt{5}b$, $\sqrt{7}b$, and so on, and to draw the lines representing their common axes from the data of diagram III. Now number the zones between successive pairs of circles 1, 2, 3, . . ., and mark on the diagram—which, of course, is drawn on squared paper—the position on the plate of a star for which Δx is required. Suppose the coordinates of the star, *referred to the axes of the ellipses*, are u, v. The point (u, v) lies inside or outside a certain ellipse, according as the point $(u/a, v)$ lies inside or outside the corresponding auxiliary circle. Hence, if we take a pair of proportional compasses set to the ratio a/b, it is a matter of a few seconds only to determine for each star between which pair of ellipses it lies, and consequently what the correction is for the second-order terms of the differential refraction.

Diagram I. gives b for any values of X and Y, without discriminating whether the conic is an ellipse or hyperbola. Diagram II. shows with a thick line the curve of $a/b=\infty$, which gives the boundary between the ellipses and hyperbolas. Occasionally it will be found that the first hyperbola of a set just comes on to the corners of a plate—that is to say, that the corresponding correction is just more than half one in the last place. If it is not considered legitimate to neglect so small a correction, it will at least be sufficient to sketch in the hyperbolas freehand ; and this I have done in the example which follows.

It will be noted that when we have an hyperbola bounding

a region of positive correction, the conjugate hyperbola bounds a region of equal negative correction, and must also be drawn in.

12. It does not seem to be necessary to go into details about the way the rules of signs have been found. The rules, as they are given in diagrams I.–III., follow almost immediately from the theory, and it is easier to deduce them afresh than to read an explanation of how they were deduced at first.

13. Let us take an example of the way in which, by the aid of diagrams I., II., and III., a refraction diagram can be drawn for any plate taken anywhere in the world.

Among the measures of photographs of *Eros* and comparison stars communicated to Cambridge by the kindness of the directors of several Observatories, is a plate taken at San Fernando, 1900 November 15, S.T. $22^h\ 15^m\ 27^s$. The approximate coordinates of its centre are

$$\text{R.A. } 1^h\ 47^m\ 0^s \qquad \text{Decl. } +54°\ 0'$$

For the coordinates of the projection of the zenith on the plate (expressed in parts of the focal length) we find

$$X = -0{\cdot}837 \qquad Y = -0{\cdot}056$$

and the diagrams give the following data for the conics:

Δx *conics.*

$b = 8{\cdot}85$ $\quad a/b = 1{\cdot}64$ $\quad q+\phi = \cot^{-1}(0{\cdot}05)$

$\sqrt{3}.b$ $\quad 15{\cdot}3$ $\quad$ Ellipses :

$\sqrt{5}.b$ $\quad 19{\cdot}8$ $\quad$ Corrections positive.

$\sqrt{7}.b$ $\quad 23{\cdot}5$

$\sqrt{9}.b$ $\quad 26{\cdot}6$

Δy *conics.*

$b' = 18{\cdot}3$ $\quad a'/b' = \sqrt{-1} \times 1{\cdot}4$ $\quad q+\phi' = \tan^{-1}(0{\cdot}96)$

Hyperbolas :

Corrections positive.

And in the conjugate hyperbolas corrections negative.*

The resulting plate diagram is shown in figs. 2 and 3. The Δx and Δy diagrams have been kept separate for the sake of clearness on the small scale of the reproduction. For the same reason every tenth line only of the squared paper has been shown. In practice the two diagrams are drawn on the same centre, one of them in red ink. And there is no confusion unless the zenith distance is great and the circles very close together. The paper used is ruled with ten squares to the inch; and one-tenth of an inch on the diagram corresponds to our unit, the thousandth of the focal length, or $3'{\cdot}438$ nearly.

The thick lined square represents the extreme limits of

* In the figure I have shown the conjugate hyperbolas wrong. Their vertices should come just on to the corners of the plate.

measurement on an astrographic plate. The minor axes of the conics are distinguished by the arrowhead. The stars for which

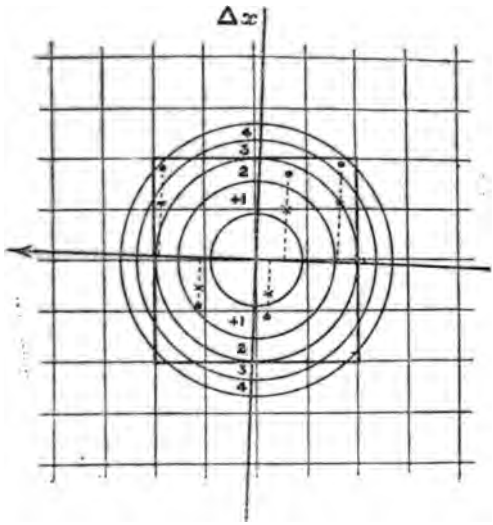


FIG. 2.

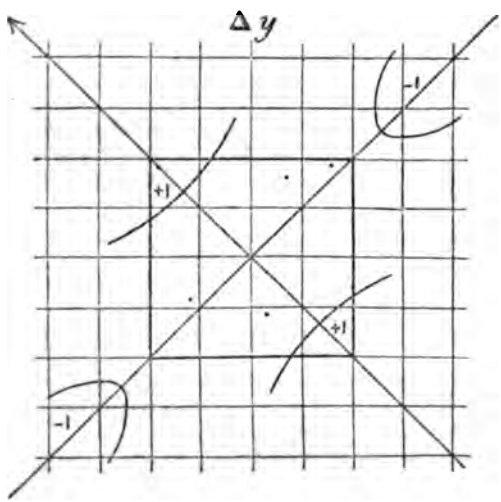


FIG. 3.

the corrections are wanted are plotted on the plate diagram, and the proportional compass is set to the ratio 1 : 1·64. The perpendiculars to the minor axis from the stars are thus divided in

the ratio 100 : 64 ; the points of division are shown by crosses and it follows from the way these points have been found tha they are on the auxiliary circles of the ellipses of the serie which pass respectively through the stars. They will therefor be inside or outside the auxiliary circles drawn on the diagram according as their corresponding stars are inside or outside the ellipses which bound the zones of given correction.

The use of these diagrams is far more difficult to describe than it is to acquire. And in three cases out of four it is un necessary to draw perpendiculars or to use the compasses at all ; it is obvious by inspection in which zone the "auxiliary circle point" will fall.

For instance, take the case of the five stars shown on the Δx diagram of the example. If we count from left to right it would have been obvious by inspection that the corrections for the first four stars are + 3, + 1, 0, + 1. For the fifth the auxiliary circle point comes very near the circle dividing zones 2 and 3 ; on drawing it we find that it is just inside the circle, and the correction is + 2.

As for the Δy corrections, that of the first is + 1, and of the others zero.

14. It is proper to remark here that occasionally—in perhaps 1 per cent. of cases—there will be a doubt whether the diagram has been drawn with sufficient accuracy to discriminate, we will say, between 2 and 3 ; the auxiliary point is practically on the dividing line. This means, of course, that the real correction is $2\frac{1}{2}$, and it is immaterial whether we call it 2 or 3. The diagram never introduces, therefore, any sensible inaccuracy.

15. I have recently used these diagrams for finding the second-order refraction corrections on a considerable series of *Eros* plates ; and it seems to me that they are a real working advantage. A rough estimate of the time required to correct a plate by their aid is :

Calculation of X and Y ... 5 min.

(this has to be done anyhow).

Drawing the plate diagrams ... 1—15 min.

(this depends entirely on the zenith distance. In many cases one finds immediately that there is no diagram wanted ; the first conic is outside the limits of the plate).

When the plate diagram is drawn the star corrections can be taken from it at the rate of four or five a minute at least.

Finally, a particular advantage of this method is that it saves all worry about whether second-order refraction terms are sensible or not, and all danger of neglecting them by inadvertence or otherwise. It is so easy to work off the diagrams for a whole set of plates that one finds it easier to draw the diagram

for every plate than to consider whether it will be necessary to do so in particular cases.

In the calculation of the tables from which the diagrams were drawn I have received valuable assistance from Miss Julia Bell and Miss Hilda Gibb, of Girton College, to whom my acknowledgments are due.

We are indebted to the Government Grant Fund of the Royal Society for a grant to secure their assistance in the reduction of the *Eros* photographs.

Cambridge Observatory: 1903 *January* 3.

Note on the Use of Mr. Aldis' Tables of the Function $\frac{1}{2}(\theta + \cos\theta)$ *in Determining the Elements of an Orbit.* By H. C. Plummer, M.A.

1. In the second part of his explanation* of the use of tables of $\frac{1}{2}(\theta + \cos\theta)$ Mr. Aldis has shown that they can be applied to the problem of finding the elements of an elliptic orbit when two focal distances, the angle between them, and the time occupied in passing from one position to the other are known. An inspection of the example which he has worked out makes it evident that the practical utility of the method may be greatly enhanced if a convenient way can be devised of finding preliminary approximations to the values of the quantities required. It is the object of this note to supply the want. A graphical method will be first described; but this is to be regarded chiefly as the basis of the analytical method of approximation which follows.

2. By the use of Lambert's theorem the problem is reduced to the solution for a, ϵ, and δ of this system of three equations:

$$\frac{kt}{a^{\frac{3}{2}}} = (\epsilon - \sin\epsilon) - (\delta - \sin\delta) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$$1 - \cos\delta = \frac{r + r' - c}{2a} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$$1 - \cos\epsilon = \frac{r + r' + c}{2a} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

The notation is that of Mr. Aldis' paper. When a is known the eccentricity e can be easily deduced. It will be convenient to write

$$\sigma_1^2 = r + r' + c\,; \quad \sigma_2^2 = r + r' - c.$$

Now if

$$x_1 = \delta - \sin\delta\,; \quad y_1 = 1 - \cos\delta$$

$$x_2 = \epsilon - \sin\epsilon\,; \quad y_2 = 1 - \cos\epsilon$$

* *Monthly Notices*, vol. lxii. p. 638.

x_1, y_1 and x_2, y_2 are the coordinates of points lying on the cycl whose equations are

$$x = \theta - \sin\theta\,;\ y = 1 - \cos\theta$$

The coordinates are also connected by the relations

$$kt = a^{\frac{1}{2}}(x_2 - x_1)$$
$$2ay_1 = \sigma_2^2\,;\ 2ay_2 = \sigma_1^2$$

If a be eliminated we have

$$2\sqrt{2}kty_1^{\frac{1}{2}} = \sigma_2^3(x_2 - x_1)$$
$$2\sqrt{2}kty_2^{\frac{1}{2}} = \sigma_1^3(x_2 - x_1)$$

3. These equations have a geometrical interpretation. L p and q (fig. 1) be the points (x_1, y_1) and (x_2, y_2) on the cycloi

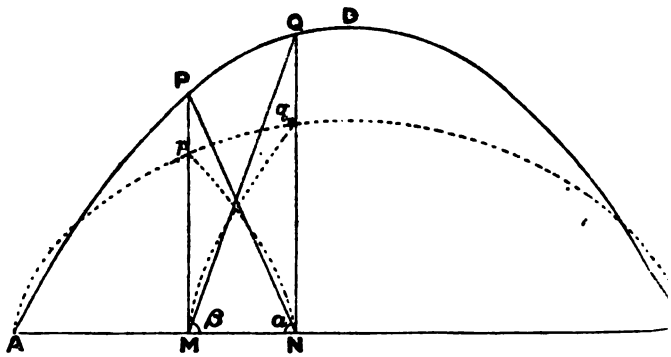


FIG. 1.

ACB. The meaning of the equations is that semi-cubi parabolas with known parameters and axes parallel to $x = 0$ w pass respectively through p and q when their vertices are N and M, the feet of the ordinates at q and p. It then becon evident that the figure will be greatly simplified by a tra formation which corresponds to the substitution

$$x = X\,;\ y^{\frac{1}{2}} = Y$$

i.e. by raising each ordinate to the power $\frac{2}{3}$. The derived cu ADB (fig. 1) which replaces the cycloid has for its equations

$$X = \theta - \sin\theta\,;\ Y = (1 - \cos\theta)^{\frac{1}{2}} = 2\sqrt{2}\sin^3\tfrac{1}{2}\theta \ \ldots$$

The semi-cubical parabolas are replaced by the straight li PN, MQ, inclined to AB at angles α, β, such that

$$\tan\alpha = \sigma_2^3/2\sqrt{2}kt\,;\ \tan\beta = \sigma_1^3/2\sqrt{2}kt \quad \ldots$$

raphical method of finding the required approximations
gested. The curve ADB given by (4) must first be
d on squared paper, and the base line AB may
ly be graduated in θ. Then it is necessary to place
N, QM at known inclinations to the base in such a
at their intersections with the curve project (as in
to their intersections with the base. A convenient
ng this is to draw the lines PN, QM on ground glass,
rd line in the direction of the base, and to move the
btained over the paper until as good a fit as possible is
Rough values of ϵ and δ can then be read off. But
l of the method in one or two cases has seemed to
it is not susceptible of any great accuracy. This is in
asure due to the fact that the given interval of time
ral small. The analytical method of approximation
e described takes advantage of this fact, and will
e more effective as the graphical method becomes more
ble.

ig. 2, which corresponds to the essential part of fig. 1,

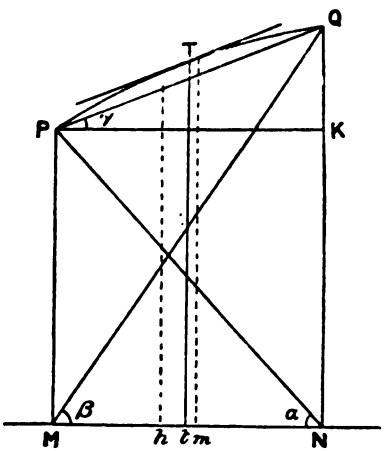


FIG. 2

drawn parallel to MN, and let the angle QPK $= \gamma$.
is easily determined, for

$$\tan\gamma = \tan\beta - \tan\alpha$$

the point of contact of that tangent to the curve which
to PQ, and let $\theta = \tau$ at this point. It is easily found

$$\tan\gamma = \frac{3}{\sqrt{2}}\cos\tfrac{1}{2}\tau$$

Hence by (5)

$$\cos \tfrac{1}{2}\tau = (\sigma_1^3 - \sigma_2^3)/6kt \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

a result which presents a curious analogy to Euler's theorem. In fact, the latter is hereby deduced from Lambert's theorem * if it is noticed that, in the limiting case of the parabola, $\delta = \epsilon = \tau = 0$.

6. It will be convenient to put

$$2\eta = \epsilon + \delta\,; \quad 2\zeta = \epsilon - \delta \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

Now τ must clearly lie between δ and ϵ, and is indeed a good first aproximation to the value of η. Let ζ_1 be the corresponding value of ζ which makes (2) and (3) consistent. But these equations give

$$\sigma_1 \sin \tfrac{1}{2}\delta = \sigma_2 \sin \tfrac{1}{2}\epsilon$$

which can be written in the modified form

$$\tan \tfrac{1}{2}\zeta = \frac{\sigma_1 - \sigma_2}{\sigma_1 + \sigma_2} \tan \tfrac{1}{2}\eta \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

Hence

$$\tan \tfrac{1}{2}\zeta_1 = \frac{1-n}{1+n} \tan \tfrac{1}{2}\tau \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

where $n = \sigma_2/\sigma_1$. Thus τ and ζ_1 are found very easily by (6) and (9), and the corresponding approximations to δ and ϵ are deduced immediately.

7. It is now easy to see how the approximation can be improved by a simple step. Let (fig. 2) t be the foot of the ordinate through T, m the foot of the ordinate midway between PM and QN, and h the foot of the ordinate through the point for which $\theta = \frac{1}{2}(\epsilon + \delta)$. Let $y = \phi(x)$ be the equation of the curve and x and $x+h$ the abscissæ of P and Q. Then by a well-known theorem

$$\frac{\phi(x+h) - \phi(x)}{h} = \phi'(x + fh)$$

where

$$f = \tfrac{1}{2} + \tfrac{1}{24} \cdot \frac{\phi'''(x)}{\phi''(x)}\, h$$

if the expansion of f is not carried beyond the first power of x. Hence

$$tm = -\tfrac{1}{24} \cdot \frac{\phi'''(x)}{\phi''(x)}\, h^2$$

* Adams has given a simple proof that Euler's theorem can be deduced as a limiting case.—*Collected Scientific Papers*, vol. i. p. 413.

And if $x=\psi(\theta)$ and θ becomes $\theta+\Delta\theta$ at Q, then

$$km = \tfrac{1}{2}\psi(\theta)+\tfrac{1}{2}\psi(\theta+\Delta\theta)-\psi(\theta+\tfrac{1}{2}\Delta\theta)$$
$$= \tfrac{1}{8}\psi''(\theta)\,.\,\Delta\theta^2$$
$$\therefore ht = \left\{\tfrac{1}{8}\psi''(\theta)+\tfrac{1}{24}\,.\,\frac{\phi'''(x)}{\phi''(x)}\,[\psi'(\theta)]^2\right\}\Delta\theta^2$$
$$= +\tfrac{5}{48}\sin\theta\,.\,\Delta\theta^2$$

when the differentiations are performed. The correction to be applied to τ in order to give a second approximation to the value of η is therefore

$$-ht\div\psi'(\theta) = -\tfrac{5}{48}\cot\tfrac{1}{2}\theta\,.\,\Delta\theta^2$$

If, as above, the calculation is made in terms of the lower end of the chord, $\theta=\delta$; and starting from the upper end we should find $\theta=\epsilon$. It is therefore natural to adopt $\theta=\tau$. Also $\Delta\theta=2\zeta$. Hence it is inferred that if

$$\Delta\tau = -\tfrac{5}{12}\cot\tfrac{1}{2}\tau\,.\,\zeta^2 \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

then $\tau+\Delta\tau$ is the second approximation to the value of η, from which improved values of ϵ and δ can be deduced in the manner already explained. All the angles occurring in the foregoing formulæ and the constant k are supposed to be expressed in circular measure.

8. The result of practical trials is to show that the method is extremely effective. In the first instance the example which was taken by Mr. Aldis from the *Theoria Motus* was tried. This gave

$$\tau = 7^\circ\ 38'\ 21''\cdot6\,;\quad \zeta_1 = 3^\circ\ 8'\ 21''\cdot6\,;\quad \epsilon_1 = 81^\circ\ 46'\ 43''\cdot2$$
$$-\Delta\tau = \quad 5\ 14\cdot8\,;\quad \zeta_2 = 3\ 8\ 4\cdot0\,;\quad \epsilon_2 = 81\ 41\ 10\cdot8$$

Now Mr. Aldis finds for the correct value of ϵ, $81^\circ\ 41'\ 11''\cdot5$, and hence for $\log a$, 0·4224385, while the value given by Gauss for $\log a$ is 0·4224389. The above value of ϵ_2 gives $\log a$ = 0·4224400. And if $\Delta\tau$ is recalculated by means of ζ_2 in the place of ζ_1, the correct value of ϵ is obtained. A second trial was made with an artificial example given by Dr. Moulton* in which the eccentricity was unusually large. In this case the value assigned to a was 2·65. The logarithms of three radii vectores are given only to six figures. The value found for ϵ_2 from the shorter period of thirty days gives $a=2\cdot650063$, which shows a fair agreement with the value actually assigned. But if the extreme places of the planet, with an interval of sixty-five days, are taken, the case is by no means so good. From the value found for ϵ_2, $a=2\cdot6519$. It is true that an improvement might be made by recalculating $\Delta\tau$ as mentioned above, but the

* *Astr. Journal*, No. 510.

method would lose the advantage of its simplicity thereby. It is better to treat ϵ_2 as an approximation which facilitates the use of Mr. Aldis' tables. Cases in which the interval of time is so long must occur very rarely, if at all, in the practical applications of the problem. But in such cases, and whenever the highest degree of accuracy is required, the value of the tables, as far as this problem is concerned, will consist in giving the final improvement, or at least the verification, to approximate solutions found by some preliminary method.

9. It is, however, desirable to examine the nature of the second approximation more closely. The tangent to the curve (4) at the point $\theta=\tau$ is parallel to the chord joining the points $\theta=\eta-\zeta$ and $\theta=\eta+\zeta$. Therefore

$$\tfrac{3}{4}\cos\tfrac{1}{2}\tau=\frac{\sin^3\tfrac{1}{2}(\eta+\zeta)-\sin^3\tfrac{1}{2}(\eta-\zeta)}{2\zeta-\sin(\eta+\zeta)+\sin(\eta-\zeta)}$$

$$\therefore 3\cos\tfrac{1}{2}\tau=\frac{3\cos\tfrac{1}{2}\eta\sin\tfrac{1}{2}\zeta-\cos\tfrac{3}{2}\eta\sin\tfrac{3}{2}\zeta}{\zeta-\cos\eta\sin\zeta}$$

$$\therefore \frac{3\cos\tfrac{1}{2}\tau}{2\cos\tfrac{1}{2}\eta}=\frac{\tfrac{1}{2}\zeta(3c_1-3c_3)-\tfrac{1}{6.8}\zeta^3(3c_1-27c_3)+\tfrac{1}{120.32}\zeta^5(3c_1-243c_3)-\ldots}{\zeta(c_1-c_3)+\tfrac{1}{6}\zeta^3(c_1+c_3)-\tfrac{1}{120}\zeta^5(c_1+c_3)+\ldots},$$

where

$$c_1=\cos\tfrac{1}{2}\eta\,;\quad c_3=\cos\tfrac{3}{2}\eta$$

The expansion in ζ is clearly an even function, and if terms of the order ζ^6 be neglected

$$\frac{\cos\tfrac{1}{2}\tau}{\cos\tfrac{1}{2}\eta}=\frac{(c_1-c_3)-\tfrac{1}{6.4}\zeta^2(c_1-9c_3)+\tfrac{1}{120.16}\zeta^4(c_1-81c_3)}{(c_1-c_3)+\tfrac{1}{6}\zeta^2(c_1+c_3)-\tfrac{1}{120}\zeta^4(c_1+c_3)}$$

$$\therefore \frac{\cos\tfrac{1}{2}\eta-\cos\tfrac{1}{2}\tau}{\cos\tfrac{1}{2}\tau}=\frac{\tfrac{5}{24}\zeta^2(c_1-c_3)-\tfrac{1}{10}\tfrac{1}{20}\zeta^4(17c_1-65c_3)}{(c_1-c_3)-\tfrac{1}{24}\zeta^2(c_1-9c_3)}$$

$$=\tfrac{5}{24}\zeta^2-\tfrac{1}{5760}\cdot\frac{c_1+255c_3}{c_1-c_3}\cdot\zeta^4$$

$$=\tfrac{5}{24}\zeta^2+\tfrac{1}{5760}(191-64\cot^2\tfrac{1}{2}\eta)\zeta^4$$

10. In the coefficient of ζ^4, τ may be written for η. Then

$$\sec\tfrac{1}{2}\tau\,\Delta\cos\tfrac{1}{2}\tau=\tfrac{5}{24}\zeta^2+\tfrac{1}{5760}(191-64\cot^2\tfrac{1}{2}\tau)\zeta^4$$

where $\Delta\cos\frac{1}{2}\tau$ is the correction to be added to $\cos\frac{1}{2}\tau$ to obtain $\cos\frac{1}{2}\eta$, so that

$$\Delta\cos\tfrac{1}{2}\tau=-\tfrac{1}{2}\sin\tfrac{1}{2}\tau\,.\,\Delta\tau-\tfrac{1}{8}\cos\tfrac{1}{2}\tau(\Delta\tau)^2$$

Hence, to the degree of approximation adopted,

$$\Delta\tau=-\tfrac{5}{12}\cot\tfrac{1}{2}\tau\,.\,\zeta^2-\tfrac{1}{2880}\cot\tfrac{1}{2}\tau(191+61\cot^2\tfrac{1}{2}\tau)\zeta^4$$

which confirms the formula (10) previously obtained and gives a further development. Now since

$$4\tan^2\tfrac{1}{2}\tau=\zeta^2+\tfrac{1}{3}\zeta^4$$

it is possible to write

$$\Delta\tau=-\tfrac{1}{3}\cot\tfrac{1}{2}\tau\tan^2\tfrac{1}{2}\tau-\tfrac{1}{2\,8\,8\,0}\cot\tfrac{1}{2}\tau(61\cot^2\tfrac{1}{2}\tau-9)\zeta^4\ldots\quad(11)$$

Therefore if powers of ζ above the third be neglected it is more accurate to write (10) in the form

$$\Delta\tau=-\tfrac{1}{3}\cot\tfrac{1}{2}\tau\tan^2\tfrac{1}{2}\tau$$

which again, by means of (9), may be expressed

$$\Delta\tau=-\tfrac{1}{3}\left(\frac{1-n}{1+n}\right)^2\tan\tfrac{1}{2}\tau\quad\ldots\quad\ldots\quad\ldots\quad(12)$$

Thus the second approximation to η may be derived directly from (6) and (12) before an approximation to ζ has been calculated. The work to this stage will therefore be very rapid, and it will be easy to judge from the value then found for ζ whether it is worth while to refine on the approximation by means of (11).

11. The representation of the consequences of Lambert's theorem by means of a curve related to the cycloid was suggested by the method I have previously described * for finding graphically an approximation to the solution of Kepler's equation by means of the trochoid. The application of Mr. Aldis' tables to the latter problem will be rendered more advantageous by using them as an auxiliary to some such approximate method as the one to which I refer. My description of that method was not, as it soon appeared, original. It had, for instance, been published by Dr. Rambaut † a few years earlier; and quite lately it has again been brought forward by B. Gonggrijp. ‡ But the principle of the method is as old as Wallis and Newton.

Note added 1903 *Jan.* 24.

The purpose of the foregoing note was, as explained in the beginning, merely to supply an approximate method which might serve to facilitate the use of Mr. Aldis' tables, and the examples mentioned in § 8 suffice to show that this object has been fully attained. But the method as further developed in §§ 9 and 10 is something more than a mere auxiliary to the tables. It provides an adequate and convenient means of solving Lambert's equation in cases of moderate difficulty without the aid of any special tables.

The essence of the method is contained in the equations (6),

* *Monthly Notices*, vol. lvi. (1896), p. 317.
† *Ibid.* vol. l. (1890), p. 301.
‡ *A. N.* (1901), No. 3720.

(8) and (11), by means of which the values of η and ζ are found by successive approximations. It is well to remark that

$$\zeta = \tfrac{1}{2}(E' - E)\,;\ \cos\eta = e\cos\tfrac{1}{2}(E' + E)$$

where E, E′ are the eccentric anomalies of the planet; and that

$$ap = rr' \sin^2\Delta \operatorname{cosec}^2\zeta$$

where 2Δ is the difference of the true anomalies. This explains the nature of the expansion (11), which might, if necessary, be developed further without serious difficulty. Its advantage consists in its rapid convergence for moderate values of ζ and in the fact that to the order ζ^5 it consists of only two terms, of which the second is very small. For actual calculation (11) may be written in the form

$$-\tfrac{1}{2}\Delta\tau = Z + FZ^2 \qquad \ldots \quad \ldots \quad (11')$$

where

$$Z = \tfrac{2}{3}\cot\tfrac{1}{2}\tau\tan^2\tfrac{1}{2}\zeta$$
$$F = \tfrac{1}{2}\tfrac{1}{5}\tfrac{1}{0}(61 - 9\tan^2\tfrac{1}{2}\tau)\cot\tfrac{1}{2}\tau$$

When log Z is found, Z can be taken from a table of logarithmic sines; and the following table, which will apply to eccentricities of at least 0·5, gives log F in such a way that the term FZ^2 will be found in seconds of arc :—

Table of log F.

½τ.	log F.	Diff.	½τ.	log F.	Diff.	½τ.	log F.	Diff.
°			°			°		
30	4·9186		40	4·7305		50	4·5238	
		−192			−190			−240
31	·8994		41	·7115		51	·4998	
		190			193			250
32	·8804		2	·6922		52	·4748	
		189			195			26
33	·8615		43	·6727		53	·4486	
		187			198			27
34	·8428		44	·6529		54	·4210	
		187			202			29
35	·8241		45	·6327		55	·3919	
		186			206			31
36	·8055		46	·6121		56	·3609	
		187			212			33
37	·7868		47	·5909		57	·3277	
		186			217			33
38	·7682		48	·5692		58	·2919	
		188			223			35
39	4·7494		49	4·5469		59	·2529	
		−189			−231			−40
						60	4·2099	

The more complete formulæ have been applied to the example already mentioned in § 8, in which the interval of time is 65 days and the eccentricity 0·3. The result is quite satisfactory, and shows that the formulæ are as accurate as the data require. As the second interval between the observations does not enter into this part of the computation, and is therefore unlimited, this example is a far more severe test than when two intervals of 30 and 35 days are used. The additional term FZ^2 amounts

to 4″·77. It may be necessary, as it is in this case, to repeat the calculation by means of (8) and (11′) two or three times, but the process is in practice very simple and rapid. It is convenient to use logarithmic tables giving every second of arc (*e.g.* Bagay's), to keep the openings for $\frac{1}{2}\eta$, $\frac{1}{2}\zeta$, and $\frac{1}{2}\Delta r$ marked, and instead of repeating the whole of the figures (which in any case are very few) it is sufficient merely to write the *corrections* in parallel columns. In fact, when σ_1 and σ_2 are known it takes very little time to find η and ζ, and hence a, p and e. The method is summarised in the following scheme :—

Summary of Calculation.

(1) Calculate σ_1, σ_2 by means of

$$\sigma_1^2 = r+r'+c\ ;\ \sigma_2^2 = r+r'-c$$

(2) Calculate $n = \sigma_2/\sigma_1$, and hence $\log N = \log(1-n) - \log(1+n)$

(3) Find $\frac{1}{2}r$ by means of

$$\cos\tfrac{1}{2}r = (\sigma_1^3-\sigma_2^3)/6kt$$

(4) Find $\frac{1}{2}\Delta r$ from

$$\tfrac{1}{2}\Delta r = -\tfrac{5}{8}N^2\tan\tfrac{1}{2}r$$

(5) Hence $\frac{1}{2}\eta_2 = \frac{1}{2}(r+\Delta r)$, and ζ_2 can be found from

$$\tan\tfrac{1}{2}\zeta_2 = N\tan\tfrac{1}{2}\eta_2$$

(6) With ζ_2 as an approximate value of ζ find $\log Z$ from

$$Z = \tfrac{5}{8}\cot\tfrac{1}{2}r\tan^2\tfrac{1}{2}\zeta$$

and recalculate $\frac{1}{2}\Delta r$ by means of

$$-\tfrac{1}{2}\Delta r = Z+FZ^2$$

(7) If necessary repeat the operations (5) and (6) until the equations

$$-\tfrac{1}{2}(\eta-r) = -\tfrac{1}{2}\Delta r = Z+FZ^2$$
$$\tan\tfrac{1}{2}\zeta = N\tan\tfrac{1}{2}\eta$$

are both satisfied.

(8) When η and ζ are thus known with sufficient accuracy a is found from

$$a = \sigma_1^2/4\sin^2\tfrac{1}{2}(\eta+\zeta)$$

and p from

$$ap = rr'\sin^2\Delta\operatorname{cosec}^2\zeta$$

Finally the eccentricity is found from a and p.

University Observatory, Oxford:
1903 Jan. 8.

On a New and Accurate Method of Determining Time, Latitude, and Azimuth with a Theodolite. By W. E. Cooke, M.A., Government Astronomer, Western Australia.

The *principle* of this method is not new. It was, I believe, first advocated by Mr. S. C. Chandler, who designed an instrument which he called an "Almucantar," developed the mathematical theory, and made a series of very fine observations at the Harvard College Observatory. An instrument of that kind, however, does not form part of a surveyor's ordinary outfit, whilst a theodolite does; and my present purpose is to show how the method may be applied to this universal instrument, and how by its means results of far greater accuracy than those usually obtained may be deduced. Briefly, the spirit level can be used instead of a mercury flotation in order to ensure constancy in zenith distance, and this brings the method within the power of every surveyor.

I shall first show it in connection with a 5-inch theodolite, and state the results of a few observations already made. Afterwards I propose to show that with a 12-inch instrument results can be obtained which, I believe, exceed in accuracy anything in field work hitherto published.

Five-inch Theodolite.

The observation for time and latitude consists in observing the time of transit of *Nautical Almanac* stars over the horizontal thread when the instrument is set so as to sweep a small circle in the sky parallel with the horizon, and at an altitude *about* equal to the observer's latitude. For azimuth it will be necessary, in addition, to take the time of transit across the vertical thread and to read the azimuth circle. An ordinary watch which possesses a seconds hand will do for timekeeper. The advantages may as well be enumerated here.

For time and latitude errors of vernier reading do not exist, as we require the circles for approximate setting purposes only. Extreme accuracy of construction and adjustment is unnecessary. We require only ordinary care in levelling. Error of collimation is absolutely immaterial. We do not even require that the bubbles shall be properly adjusted. All we require in the way of adjustment is that the vertical axis shall be reasonably vertical, so that the cross bubble on the altitude circle shall remain *fairly* steady as the instrument is swung round in azimuth, and great accuracy is not required even for this. As a matter of fact the instrument I used had been standing in a corner for months, and I simply took it out and levelled it up.

Yet, notwithstanding this apparent want of respect, results of considerable accuracy may be easily obtained. Those obtained in two evenings' trial will be stated almost immediately.

For azimuth I am afraid we must still depend upon the accuracy of the circles, and this immediately introduces errors which appear absurdly large compared with those for time and latitude. Incidentally it shows what an advance has been made by adopting this method. But even for azimuth it is confidently believed that the portion of error due to the star observation is greatly reduced, and that as the result of an evening's work the instrumental error is deduced with an accuracy far exceeding the possible setting. I may state here that I am not a practised observer with a theodolite, and possibly those who are may be able to read the circle itself with greater accuracy; but with a flickering candle-lamp I found it sometimes difficult to see any marked difference between two adjoining vernier divisions, and I think it is doubtful whether any surveyor would care to guarantee his accuracy within 1′ for each of a series of stars, some of the readings of which had to be made rather hurriedly. For azimuth, then, it can only be claimed that errors due to the star observation itself are probably reduced considerably, and that the observation can be conveniently made at the same time as the others, one setting being all that is required for each star, from which time, latitude, and azimuth are all deduced.

And now the results may be given for comparison with other methods, after which I shall show how the observations were made and reduced. I used a 5-inch theodolite, a candle lamp, and an ordinary watch. I had one vertical and one horizontal wire and no assistant. The watch did not tick either seconds, half-seconds, or any particular fraction of a second, and I had to get the time of transit the best way I could. I compared the watch during the evening with the standard sidereal clock, and thus I know its exact error. I observed on two evenings, with the following results :—

Time.

	Watch fast by direct comparison with sidereal clock.	Watch fast by observation of stars.
	m s	m s
1902 Dec. 17 ...	1 27·1	1 26·9
18 ...	2 01·8	2 01·9

Latitude.

	°	′	″
Dec. 17 ...	31	57	10·9
18 ...	31	57	09 6

The real value of latitude is unknown to a fraction of a second, as the errors of division of the transit circle have not yet been determined; but it is, as nearly as I can obtain it, almost exactly midway between these two values. Such a remarkable agreement with a 5-inch instrument and common watch might be regarded as a mere coincidence were not its general accuracy determined by other considerations. It will, for instance, be found that the 12-inch gave quite unexpected agreement over

five nights. The principle upon which the observations are made produces confidence. And in particular the individual results show very satisfactory inter-agreement. I reproduce here those for the 18th, which are the better, as on the 17th I was new to the method and rather flurried at times.

Individual Results for each Pair, December 18.

Time.		Latitude.		
m	s	°	′	″
2	01·8	31	57	10·4
	1·5			9·0
	1·4			10·6
	2·3			8·4

The mean of the four watch errors does not agree exactly with that already given, but I had a ninth star unappropriated which was worked in.

I am, of course, willing to allow something for luck in such very close work; but I think it would not be possible to obtain anything like such results by the methods at present adopted.

Definitions.

I wish to define a few terms first. Let us adopt Chandler's name for the circle of reference. The almucantar, or small circle parallel to the horizon which passes through the celestial pole, will be called "the colatitude circle." There are in an ordinary 5-inch theodolite two screws which move the telescope in altitude when clamped. One moves it without disturbing any bubble. Let us call this one X. The other, usually consisting of a pair of antagonistic screws, moves both the telescope and the bubble to which the altitude circle is clamped. Let us call this screw Y, and it is particularly important to note the difference. X moves the telescope only, Y moves both telescope and bubble. This bubble we shall speak of as "the bubble." It is, in my instrument, the largest bubble of any except the stride, and extends from edge to edge of the vertical circle. It is the essential feature of the whole scheme, and the more sensitive it is the better. In mine one division equals 20″.

Other Definitions.

ϕ = observer's latitude, considered always positive.

α = star's R.A.

δ = star's declination, N being + and S −.

t = star's hour angle, + if west, − east.

θ = sidereal time of transit across colatitude circle.

A = star's azimuth at transit across colatitude circle.

Practice.

1. Prepare a working list of stars beforehand. Any stars down to the fifth magnitude may be taken from the *Nautical Almanac*. Two series are required. Let us call these

(*a*) *Prime vertical stars*, or those which cross the colatitude circle within about 20° N. or S. of the prime vertical. For Perth I take 0° to 30° south declination.

(*b*) *Latitude stars*, or those remote from the pole, whose hour angle is not greater than $2\frac{1}{2}$ hours, *i.e.* whose polar distance is within a few degrees, say 10°, of $(180°-2\phi)$. Of course it must be *less* than this quantity in order that the star may cross the colatitude circle.

Compute the sidereal time of observation and azimuth approximately by the following formulæ :—

$$\theta = \alpha + t$$

$$\text{where } t = \begin{cases} \tan\phi \tan(45°-\frac{1}{2}\delta) \text{ for northern latitudes} \\ \tan\phi \tan(45°+\frac{1}{2}\delta) \text{ for southern latitudes} \end{cases}$$

and $$\tan\tfrac{1}{2}A = \phi \tan t$$

using the best available value of ϕ for this purpose.

2. Set up and level instrument; in particular see that the level just mentioned is about the middle of its run. Set the telescope at an altitude $= \phi +$ refraction, using approximate values, of course the closer the better. Screw X may be used for this purpose, but after the first star is taken it must not be touched until the set is complete. A few minutes before the first star is expected, set for it in azimuth and clamp ; and now set "the bubble" quite accurately by means of screw Y. This must be done as carefully as possible. It is, in fact, the one essential adjustment, and a readjustment by screw Y must be made just before each star is taken. If when the star is seen in the field it appears that it will not cross the horizontal wire at the computed time the altitude may be altered by means of screw X ; but this applies to the first star only. The reason for the error will be an inaccurate telescope setting, or perhaps a large error in horizontal collimation. It may be adjusted approximately prior to the first transit, but afterwards must not be handled. It should perhaps be pointed out that this adjustment is purely a matter of convenience. The observations will give correct results even with a fairly large error of adjustment, but "the bubble" *must* be adjusted at some standard reading before each observation, the best being obviously the position of mid-level.

If the star appears to be moving in such a manner that it will not pass near the intersection of the wires the azimuth slow-motion screw may be used at any time.

3. Observe the times of transit across the horizontal and vertical wires, moving the azimuth screw so that the star crosses near, but not quite at, the centre. Do not touch the azimuth screw after transit of the vertical wire, or if you do, move it so that the star has to cross the wire again and take the second transit instead of the first. Then read the azimuth circle.

If only time and latitude are required take the horizontal transit only, and do not trouble about the azimuth circle.

Computation.

By means of the bubble we have observed the transit of a number of stars over the horizontal wire at some one definite zenith distance, *i.e.* over a definite almucantar, the accuracy of which depends upon the accuracy with which we have adjusted the bubble each time. We are supposed to have observed a few prime vertical and a few latitude stars, both east and west of the meridian, and if the number observed is equally divided between east and west so much the better.

From the prime vertical stars we shall find first the quantity Z, whereby the circle actually traced by the instrument differs from the true colatitude circle, and secondly the watch error.

From the latitude stars combined with Z, just obtained, we shall compute our latitude.

From any of the stars we shall compute the instrumental error in azimuth.

Our method requires that the latitude should be approximately known. If it is known with fair accuracy we may go straight ahead, but if not it will be as well to make a preliminary computation, taking one pair of prime vertical stars for Z and one pair for latitude. This will give us a result quite accurate enough for use.

Computation for Time.

With this value of latitude compute rigorously for each star values of θ and A by the formulæ already given, but use now seven-figure logs and take angles out to seconds at least. Compute also with four-figure logs

$Z = \operatorname{cosec} t \sec \delta$. Z is + for west and − for east stars in all latitudes. This quantity is required for every star.

$L = \frac{2}{15 \sin 2\varphi} \cdot \cot t$. Same sign as Z. Required for latitude stars only.

If τ represents the observed time of transit reduced to sidereal time, form the quantity $(\theta+\tau)$ for each star. Distinguish eastern observations with an accent. Thus $(\theta-\tau)$ for west and $(\theta'-\tau')$ for east, &c. If the watch is fast this quantity will probably be negative, and if slow positive. Arrange the prime

vertical stars in two columns, west and east stars, and opposite each star place its Z and $(\theta - \tau)$. Take the mean of each of the four columns. We shall thus have mean values of Z, $(\theta - \tau)$, Z′, and $(\theta' - \tau')$, Z and Z′ being of opposite signs.

Then $$z = \frac{(\theta - \tau) - (\theta' - \tau')}{Z - Z'}$$

The watch error is practically the mean between $(\theta - \tau)$ and $(\theta' - \tau')$, but more acurately it equals

$$(\theta - \tau) - Zz = (\theta' - \tau') - Z'z$$

Be careful about the sign of z, as the correction to latitude depends upon this.

Each pair of stars may be treated separately as above, if it be required to see how they agree amongst themselves.

Computation for Latitude.

Enter the latitude stars in two columns, east and west, and opposite each star write its Z, $\theta - \tau$, and L.

Compute $$a = (Z - Z')z$$
$$b = (\theta - \tau) - (\theta' - T')$$
$$c = L - L'$$

Then the correction to the latitude, or $\Delta\phi$, equals

$$\Delta\phi = \frac{b - a}{c}$$

and will be in seconds of arc. The sign obtained will be correct for either hemisphere, provided ϕ has been considered a positive quantity throughout; *i.e.* if $(b - a)$ is negative *subtract* $\Delta\phi$ numerically from the assumed value, and *vice versa*.

The computation may be applied to each pair separately, or to the mean of the east and mean of the west stars.

Computation for Azimuth.

Reduce the observed to sidereal time, apply the watch error, just obtained, and subtract this from the computed value of θ. Call this dt, and express it in seconds of time.

Compute $dA = 15 \sin A \cot t \,.\, dt$, using 4-figure logs, and apply this, which will be in seconds of arc, as a correction to the observed circle reading. The result will be instrumental azimuth, and the difference between it and A will be $= a$, the instrumental error in azimuth.

Observation with a 12-inch Theodolite.

The principle is the same as with a 5-inch. The modifications are :

1. The bubble is much larger. It is attached loosely, so as to revolve round the horizontal axis of the theodolite. It is set approximately level after the telescope-pointing in altitude has been made, and is then clamped firmly to the telescope. It is not adjusted before each observation. In fact, no alteration in altitude is made during the evening, but the bubble is read immediately after each transit, and a correction is made to reduce all observations to some definite level reading, arbitrarily chosen. One division is equal to 1″·2.

2. Instead of one horizontal and one vertical wire there are, in my instrument, three horizontal and five vertical ones. I make a point of obtaining transit over each of the three horizontal and as many as possible of the vertical wires.

3. The mean of the vertical wires is not necessarily in the line of collimation, but for azimuth a micrometer is used and the reading for collimation obtained. I have tried several methods, but none of them are perfectly satisfactory, in my opinion. This, however, is a trouble common to any method for obtaining azimuth, and one of the great charms of this new method of determining time and latitude is that collimation lines and circle readings are things of the past. For azimuth, however, all transits must be reduced to the vertical line of collimation.

4. A chronometer, or chronograph if available, is now used, and the results are sufficiently accurate to require a correction for diurnal aberration.

Computation.

Instead of repeating the whole method of computation I shall confine myself to indicating the change caused by the variation in the instrument.

1. Correction for bubble-reading. The value of one division of the scale must be known. Some definite bubble-reading is to be arbitrarily selected, preferably nearly the same as the mean of all the readings taken, and the difference between this standard and the observed reading, expressed in arc seconds, must be multiplied by

$$\frac{dt}{d\zeta} = \frac{1}{15 \cos\phi \sin A}$$

The result, which will be in seconds of time, must then be applied as a correction to the observed mean time of transit over the horizontal wires.

No rules for signs can be given, as these will depend upon the method of graduating, &c., and may be different in different instruments. The sign for west stars will be opposite that for east.

2. Reduction to mean of wires or line of collimation. For this purpose the interval between the mean of observed times and (*a*) the mean of wires, for horizontal, (*b*) the line of collimation, for vertical wires, must be known. To save trouble I made a point of always obtaining the three horizontal transits, and simply took the mean of the three. But this may not always be practicable, so the following formulæ are given :

Let f = angular interval of mean of observed from the ideal line to which all stars are to be referred.

F = correction to be applied.

Then for horizontal transits

$$F = Zf + \tfrac{1}{2}^{s}f^{2} \sin 1'' \cdot Z^{2} \cos t$$

and for the prime vertical set of stars only the first term need be used.

For transits over vertical threads

$$F = f \sec \phi$$

3. The correction for diurnal aberration is

$$\kappa = 0^{s}\cdot 0207 \sin \phi$$

This is to be *added* to the computed clock-error, or *subtracted* from the observed time of transit.

4. A correction for rate of chronometer should be applied to each transit, to reduce to some definite sidereal hour.

Results.

Stars were observed on five evenings, time being taken by the eye and ear method with a sidereal chronometer beating half-seconds. The chronometer was compared before and after the evening's work with the standard sidereal clock. The theodolite was placed upon a small brick pillar in the meridian of the transit circle, and the figures below show the differences between the errors of the chronometer deduced from comparison with a sidereal clock and those by direct observation with the theodolite. The error of the sidereal clock was obtained by means of transits observed with the transit circle.

	Time. Diff. *rc*—theodolite.	Latitude.
	s	° ′ ″
1902 Dec. 8	−0·03	31 57 10·3
9	+0·01	10·1
10	−0·07	10·5
12	+0·02	10·2
13	0·00	10·2

A sufficient number of observations have not been mad test azimuth results, but such as they are they appear satisfact The only rough and ready method that occurred to me wa take the instrumental error in azimuth for each night as dedu from prime vertical and latitude stars respectively. Only sets are available, as it did not occur to me to try this met for azimuth until the 12th, and even then I adopted diffe tactics for the two sets. For the prime vertical stars I kept star bisected on the middle vertical wire with the slow-mo screw in azimuth until it reached a fixed horizontal wire, took no time transits at all, reducing by a different method did not like this way, however, as well as the time transit, only used it on that one occasion; but it is satisfactory to the agreement between the two.

		P. Vert. Stars.	Latitude Stars.
		"	"
Dec. 12	Inst. error in az.	+10·2	+10·7
13	" " "	+ 4·8	+ 4·8

Of course the change between the 12th and 13th is of account. That was almost certainly a real change.

In conclusion I must express my great obligation S. C. Chandler for his work on the Almucantar published vol. xvii. of the *Annals of Harvard College Observatory*, which I refer all those who wish to see more of the mathema and results of this beautiful method.

On the Sun's Stellar Magnitude and the Parallax of Bin Stars. By J. E. Gore, M.R.I.A.

The Sun's stellar magnitude, or the number which represe the Sun's brightness as seen from the Earth on the same scal the "magnitudes" of the stars are represented, has been variou estimated at numbers ranging from $-25{\cdot}5$ to $-27{\cdot}0$. following method of computing its value from the appar brightness of binary stars, whose orbits are well determined a whose spectra resembles that of the Sun, has not, so far as I aware, been previously published.

Let P = period of binary star in years

a = semi-axis major of orbit in seconds of arc

p = parallax of binary

Then we have

$$\text{Mass of binary system} = \frac{a^3}{p^3 P^2} \text{ (Sun's mass = 1)}$$

Now if we assume the binary pair to have the same density and surface brilliancy as the Sun, we have surface of single body equivalent in mass to the binary pair

$$= \left(\frac{a^3}{p^3 P^2}\right)^{\frac{1}{3}} = \frac{a^2}{p^2 P^{\frac{2}{3}}}$$

Then, as the relative brightness is proportional to the illuminated surface, we have

$$\text{Brightness of Sun : Brightness of binary :: } 1 : \frac{a^2}{p^2 P^{\frac{2}{3}}}$$

and

$$\therefore \text{Brightness of Sun} = \frac{p^2 P^{\frac{2}{3}}}{a^2} \times \text{Brightness of binary} = B \text{ (say).}$$

Now if m = photometric magnitude of binary, we have

$$m - \frac{\log B}{0{\cdot}4} = \text{magnitude of Sun at distance of binary} = M$$

(0·4 = log "light ratio" = log 2·512)

or
$$m - \left\{ 2 \log p + \tfrac{4}{3} \log P - 2 \log a \right\} = M$$
$$0{\cdot}4$$

or
$$m - 5 \log p - \tfrac{10}{3} \log P + 5 \log a = M \quad \ldots \quad \ldots \quad (1)$$

And we have also Sun's magnitude at distance of binary (if S = Sun's stellar magnitude)

$$M = \frac{\log\left(\frac{206265}{p}\right)^2}{0{\cdot}4} + S \text{ (S being negative)}$$
$$= 5 \log 206265 - 5 \log p + S$$

or
$$M = 26{\cdot}57 - 5 \log p + S \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Equating (1) and (2), we have

$$m - 5 \log p - \tfrac{10}{3} \log P + 5 \log a = 26{\cdot}57 - 5 \log p + S$$

whence
$$S = m - 26{\cdot}57 - \tfrac{10}{3} \log P + 5 \log a \quad \ldots \quad (3)$$

This equation depends only on m, the photometric magnitude of the binary star, P its period, and a the semi-axis major of the computed orbit, and is independent of the star's parallax or distance from the Earth.

As, however, the combined surface of a pair of spheres is greater than that of a single sphere having the same mass, equation (3) will require a small correction. The amount of this correction is easily found. For let R = radius of single sphere, and r and nr = radii of two spheres having a combined mass

equal to the single sphere. Then surface of single sphere is proportional to R^2, and combined surface of the two spheres is proportional to $n^2+n^2r^2 = (n^2+1)r^2$; and we have also

$$R^3 = n^3r^3+r^3 = (n^3+1)r^3$$

and $$\therefore R^2 = (n^3+1)^{\frac{2}{3}} r^2$$

and ratio of combined surfaces of the two spheres to surface of single sphere is

$$(n^2+1)r^2 : R^2$$

or $$(n^2+1)r^2 : (n^3+1)^{\frac{2}{3}} r^2$$

or $$n^2+1 : (n^3+1)^{\frac{2}{3}}$$

If the components of the binary star are equal in size the ratio is $2 : 2\frac{2}{3}$, or $2\frac{1}{3} : 1$, or $1{\cdot}26 : 1$.

If $n = 2$, the ratio is $5 : 9^{\frac{2}{3}}$, or $1{\cdot}15 : 1$. This corresponds to a difference of about $1\frac{1}{2}$ magnitude between the components.

If $n = 4$, the ratio is $17 : 16{\cdot}166$. This corresponds to a difference of about 3 magnitudes between the components.

The correction is then made by adding the logarithm of this ratio divided by 0·4 to equation (3). For the extreme case, when the components are equal in size, the equation becomes

$$S = m-26{\cdot}57-\tfrac{10}{3}\log P+5\log a+\frac{\log 1{\cdot}26}{0{\cdot}4}$$

or $$S = m-26{\cdot}57-\tfrac{10}{3}\log P+5\log a+0{\cdot}25$$

or $$S = m-26{\cdot}32-\tfrac{10}{3}\log P+5\log a \quad \ldots \quad \ldots \quad (4)$$

Let us now apply the formula to some examples of binary stars which have a spectrum closely resembling the solar spectrum, and of which the density and surface brilliancy are probably nearly the same as the Sun's.

α Centauri. $P = 81{\cdot}1$ years, $a = 17''{\cdot}7$ (See). Photometric magnitude = 0·20 (mags. of components 0·50 and 1·75, Pickering). Spectrum of solar type. Here we have

$$\begin{aligned} S &= 0{\cdot}20-26{\cdot}57-\tfrac{10}{3}\log 81{\cdot}1+5\log 17{\cdot}7 \\ &= 0{\cdot}20-26{\cdot}57-6{\cdot}3634+6{\cdot}2398 \\ &= -26{\cdot}49 \end{aligned}$$

In this case the difference between the components bein 1·25 magnitude, the correction comes out +0·18, and hence

$$S = -26{\cdot}49+0{\cdot}18 = -26{\cdot}31$$

ξ Ursæ Maioris. $P = 60$ years, $a = 2''{\cdot}508$ (See). Ma-

= 3·93 (components 4, 4½). Spectrum solar type (G. Pickering). Here we have

$$\begin{aligned} S &= 3{\cdot}93 - 26{\cdot}57 - \tfrac{10}{3}\log 60 + 5\log 2{\cdot}508 + 0{\cdot}23 \\ &= 3{\cdot}93 - 26{\cdot}57 - 5{\cdot}927 + 1{\cdot}996 + 0{\cdot}23 \\ &= -26{\cdot}34 \end{aligned}$$

η *Cassiopeiæ*. P = 500 years, $a = 11''{\cdot}4$ (Comstock). Mag. = 3·63 (components 4 and 7·6). Spectrum second type, F 8 G (Pickering).

Here we have

$$\begin{aligned} S &= 3{\cdot}63 - 26{\cdot}57 - \tfrac{10}{3}\log 500 + 5\log 11{\cdot}4 \\ &= 3{\cdot}63 - 26{\cdot}57 - 8{\cdot}99 + 5{\cdot}28 \\ &= -26\,65 \end{aligned}$$

In this case, as there is a difference of 3·6 magnitudes between the components, the correction is very small and may be neglected.

As the parallax of *α Centauri* is known (0″·75), we can compute the Sun's stellar magnitude from it in another way. The mass of the brighter component is about equal to the Sun's mass, and the spectrum very similar (G. Pickering); we can therefore fairly compare the two bodies.

Let p = parallax of the star.

Then $\frac{206265}{p} \times 93000000$ = distance of star.

Let θ = apparent diameter of the star in seconds of arc.

Then $\theta : 206265 :: 866000 :$ distance

(866000 = Sun's diameter in miles)

and $$\therefore \quad \theta = \frac{206265 \times 866000}{\text{distance}}$$

$$= \frac{206265 \times 866000}{\frac{206265}{p} \times 93000000}$$

or $$\theta = \frac{866000p}{93000000}$$

$$= \frac{p}{107} \text{ or } = 0''{\cdot}009345p$$

For *α Centauri* we have

and $$\theta = 0{\cdot}009345 \times 0{\cdot}75 = 0''{\cdot}007$$

Brightness of sun $= \frac{(1920'')^2}{(0''{\cdot}007)^2} = \frac{3686400}{0{\cdot}000049} = 75232650000$

or the Sun is 75,232,650,000 times brighter than the brighter component of *α Centauri*.

Hence if the Sun and the brighter component of *α Centauri* have the same intrinsic brightness of surface and the same density, we have

$$(2{\cdot}512)^n = 75232650000$$

and

$$n = 27{\cdot}2$$

or the Sun is 27·2 magnitudes brighter than the brighter component of *α Centauri*. And as the photometric magnitude of the star is 0·50, we have

$$\text{Sun's stellar mag.} = (0{\cdot}50 - 27{\cdot}2) = -26{\cdot}70$$

The mean of the four results found above is

$$S = -26{\cdot}50$$

Substituting this value of S in equation (2), we have

$$\begin{aligned} M &= 26{\cdot}57 - 5\log p - 26{\cdot}50 \\ &= -5\log p + 0{\cdot}07 \\ &= 5\log\left(\frac{1}{p}\right) + 0{\cdot}07 \quad \ldots \quad \ldots \quad \ldots \quad (5) \end{aligned}$$

a simple formula for obtaining the Sun's magnitude if removed to the distance of a star whose parallax is p.

In the case of a spectroscopic binary star having a solar spectrum, if we assume that the plane of the orbit passes through the Earth, or nearly so, we can find from the observed "radial velocity" the dimensions of the system in miles, and the combined mass of the components. From these data we can compute the probable parallax of the star in the following way:

Let μ = mass of spectroscopic binary

and m = its photometric magnitude.

Then from equation (5) we have (neglecting the small constant)

$$(5\log\tfrac{1}{p} - m) \times 0{\cdot}4 = \log\mu^{\frac{1}{3}}$$

or,

$$2\log\tfrac{1}{p} - 0{\cdot}4m = \tfrac{2}{3}\log\mu$$

and

$$\therefore \log\tfrac{1}{p} = \tfrac{1}{3}\log\mu + 0{\cdot}2m \quad \ldots \quad \ldots \quad (6)$$

Or, to obtain the parallax directly from the period and com-

puted semi-axis major in miles $= d$, we have, if R = radius of Earth's orbit,

$$\mu = \frac{\left(\frac{d}{R}\right)^3}{P^2}$$

and $$\therefore \log \mu = 3 \log d - 3 \log R - 2 \log P$$

Substituting this in equation (6), we obtain

$$\log p = -\tfrac{1}{3}(3 \log d - 3 \log R - 2 \log P) - 0{\cdot}2m$$

or
$$\begin{aligned} \log p &= \tfrac{2}{3} \log P - 0{\cdot}2m + \log R - \log d \\ &= \tfrac{2}{3} \log P - 0{\cdot}2m + \log (92800000) - \log d \\ &= \tfrac{2}{3} \log P - 0{\cdot}2m + [7{\cdot}9675480] - \log d \qquad \ldots \quad (7) \end{aligned}$$

Take the case of η *Pegasi*, which is a spectroscopic binary with a spectrum of the solar type (G. Pickering). The magnitude is 3·20. The spectroscopic observations show that the period is 818 days, and the semi-axis major of the orbit about 200,000,000 miles. This gives a mass about twice the Sun's mass. Hence from equation (6) we have

$$\begin{aligned} \log \frac{1}{p} &= \frac{1}{3} \log 2 + 0{\cdot}2 \times 3{\cdot}20 \\ &= 0{\cdot}10034 + 0{\cdot}64 \\ &= 0{\cdot}74034 \end{aligned}$$

$$\therefore \frac{1}{p} = 5{\cdot}5, \text{ and } p = \frac{1}{5{\cdot}5} = 0''{\cdot}182$$

From equation (7) we have

$$\begin{aligned} \log p &= \tfrac{2}{3} \log \tfrac{818}{365} + 7{\cdot}9675480 - \log 200000000 - 0{\cdot}64 \\ &= 0{\cdot}2334986 + 7{\cdot}9675480 - 8{\cdot}3010300 - 0{\cdot}64 \end{aligned}$$

or $$\log p = \bar{1}{\cdot}2600166$$

and $$p = 0''{\cdot}182, \text{ as before.}$$

With this parallax I find, from equation (5), that the Sun would be reduced to a star of 3·77 magnitude if removed to the distance of η *Pegasi*. This makes the star 0·57 mag. brighter than the Sun, and its mass about 2·2 times the Sun's mass; a result which agrees closely with the mass derived from the spectroscopic observations.

In the case of spectroscopic binaries which have a spectrum of the *Sirian* type their light is not comparable with that of the Sun, and the above formulæ cannot be used. But we can compare them with *Sirius*, of which the parallax and mass are known, and thus deduce a probable parallax.

Taking the parallax of *Sirius* at 0″·38 and the mass of the bright star, as deduced from See's orbit,* at 2·36, let p = parallax of binary, and μ its mass computed from the spectroscopic observations. Then we have ratio of light of *Sirius* to light of spectroscopic binary

$$= \left(\frac{0{\cdot}38^2}{p^2}\right) \times \left(\frac{2{\cdot}36}{\mu}\right)^{\frac{2}{3}}$$

and if m = magnitude of spectroscopic binary, we have, taking the magnitude of *Sirius* = − 1·62

$$\log \text{ ratio of light} = \{m - (-1{\cdot}62)\} \times 0{\cdot}4 = 0{\cdot}4m + 0{\cdot}648$$

Hence

$$\log \left\{ \left(\frac{0{\cdot}38}{p}\right)^2 \times \left(\frac{2{\cdot}36}{\mu}\right)^{\frac{2}{3}} \right\} = 0{\cdot}4m + 0{\cdot}648$$

or

$$2 \log 0{\cdot}38 + \tfrac{2}{3} \log 2{\cdot}36 - 2 \log p - \tfrac{2}{3} \log \mu = 0{\cdot}4 \text{ m} + 0{\cdot}648$$

or

$$\bar{1}{\cdot}1595 + 0{\cdot}2486 - 0{\cdot}648 - 2 \log p - \tfrac{2}{3} \log \mu = 0{\cdot}4m$$

whence

$$\log p = \bar{1}{\cdot}380 - \tfrac{1}{3} \log \mu - 0{\cdot}2\, m \quad \ldots \quad \ldots \quad (8)$$

Let us take some examples of the application of this formula.

Algol. Vogel finds the mass of the bright component of this well-known variable star to be $\frac{4}{9}$th of the Sun's mass = 0·4444 × Sun.

Its photometric magnitude at normal brightness as measured at Harvard is 2·31. Hence we have

$$\begin{aligned} \log p &= \bar{1}{\cdot}380 - \tfrac{1}{3} \log 0{\cdot}4444 - 0{\cdot}2 \times 2{\cdot}31 \\ &= \bar{1}{\cdot}380 - \bar{1}{\cdot}8826 - 0{\cdot}462 \\ &= \bar{1}{\cdot}035 \end{aligned}$$

and $p = 0''{\cdot}1082$

Chandler computed a parallax of 0″·07.

Spica. Mag. 1·09. Vogel found from the spectroscopic observations a combined mass of 2·6 × Sun's mass. Assuming the bright and dark components to be equal in mass, we have mass of bright component = 1·3, and hence :

$$\begin{aligned} \log p &= \bar{1}{\cdot}380 - 0{\cdot}0379 - 0{\cdot}218 \\ &= \bar{1}{\cdot}1241, \text{ and } p = 0''{\cdot}133 \end{aligned}$$

As the star is not an *Algol* variable, the plane of the orbit

* *Researches on the Evolution of the Stellar Systems*, vol. i. p. 85.

does not probably pass through the Earth. Hence the mass is probably larger, and the parallax smaller, than that found above. No parallax has been found for this star.

β Aurigæ. Mag. 1·98. Computed mass = 5·5 × Sun's mass. In this case both components are bright, and Pickering says: "Both components appear to be equal, or nearly equal, in brightness and to have similar spectra (Spectrum A). We must therefore deduct from the constant in equation (8), $\frac{1}{2}$ log (1·26), or 0·05, and the formula becomes

$$\log p = 1\cdot330 - \tfrac{1}{3}\log\mu - 0\cdot2m$$

$$\text{or } \log p = 1\cdot330 - \tfrac{1}{3}\log 5\cdot5 - 0\cdot2 \times 1\cdot98$$
$$= \bar{1}\cdot330 - 0\cdot2467 - 0\cdot396$$
$$= \bar{2}\cdot6873, \text{ and } \therefore p = 0''\cdot04868$$

The late Professor Pritchard found by means of photography a parallax of 0″·065 and 0″·059.

ζ Ursæ Majoris. Mag. 2·18. (Both components bright.) Period according to Vogel and Eberhard 20·6 days, and mass $= \frac{4 \times \text{Sun's mass}}{\sin^3 i}$.

If we suppose $i = 90°$, $\sin^3 i = 1$, and the mass will be 4 × Sun's mass. Supposing the components to be equal in brightness, we can use the same formula as for *β Aurigæ*, and

$$\log p = \bar{1}\cdot330 - \tfrac{1}{3}\log 4 - 0\cdot2 \times 2\cdot18$$

This gives $\log p = \bar{2}\cdot6933$, and $\therefore p = 0''\cdot049$

Höffler found a parallax of 0″·0165, but a parallax of 0″·045 was found by Klinkerfues.

Castor. Mag. 1·61 (components about 1·98 and 2·98). The brighter component of this well-known binary star has been found to be a spectroscopic binary, the companion being a dark body like *Algol.* Period 2·98 days. Orbital velocity = 20·7 miles a second. If we suppose, as in the case of *Algol*, that the bright component has twice the mass of the dark companion, I find that $a = 2{,}550{,}000$ miles $(= 1{,}700{,}000 \times \frac{3}{2})$, and the mass = 0·3113 × Sun's mass. Hence mass of bright component = 0·3113 × $\frac{2}{3}$ = 0·2075, and we have

$$\log p = \bar{1}\cdot380 - \tfrac{1}{3}\log(0\cdot2075) - 0\cdot2 \times 1\cdot98$$
$$= \bar{1}\cdot2117 \text{ and } \therefore p = 0''\cdot1628$$

From heliometer measures of *Castor* made by Johnson at Oxford in 1854–55 he found a parallax of 0″·198.

The parallaxes found above for spectroscopic binaries have been computed on the assumption that the plane of the orbit passes through the Sun, or nearly so. If the orbital plane is inclined to the line of sight—as it probably is in most cases—

the mass of the system will be greater and the parallax consequently less. If the data used are correct, the computed values are therefore a maximum.

With reference to stars having spectra between the second and third types, the star λ *Andromedæ* is, I find, an interesting case. The spectroscopic observations show a period of about 19·2 days and an orbital velocity of about 5·6 miles a second. From this I find (supposing the orbit plane to be in the line of sight) a mass of only 0·0119 × Sun's mass. As the star's spectrum is K, according to Pickering it is not comparable with the Sun, and the formulæ given above cannot be used in this case; but as its photometric magnitude is 4·14, the very small mass would suggest that the star is comparatively near the Earth. If we suppose the inclination of the orbit to be 30°, the mass would be increased eight times; but even then the mass would be less than one-tenth of the Sun's mass.

Dublin: 1903 *January* 4.

New Double Stars detected with the 17¼-inch reflector during the year 1902. By T. E. Espin.

The following list contains new double stars found during 1902. The weather has been continuously bad throughout the year, and even when the sky has been clear the definition has generally been very poor. Many of the *comites* are far too faint to measure satisfactorily.

No.	B.D.	R.A. 1880. h m	Decl. ° ′	P. °	D. ″	Night.	Mags.		Note.
113	66·6	0 2·6	+66 37	122·6	6·8	1	8·5	11	...
114	66·7	3·1	66 29	161·6	5·0	3	8·7	11·2	...
115	61·50	16·3	61 34	82·4	9·9	1	8·0	10	...
116	54·87	24·6	54 59	255·9	7·7	1	8·9	8·9	...
117	54·106	27·6	55 3	54·4	3·0	1	9·0	11	...
118	63·111	47·7	63 43	241·3	2·6	2	8·6	8·7	...
119	53·271	1 10·3	54 19	115·1	5·1	1	8·2	10·5	...
120	53·576	2 41·1	53 26	70·3	3·9	1	8·7	12·5	...
121	57·729	3 24·1	57 51	325·5	6·9	2	8·0	13·5	...
122	61·666	55·3	61 50	248·7	5·0	2	8·6	10·5	...
123	44·2120	11 37·4	44 51	203·8	7·4	1	9·1	9·3	AB.
				275·5	42·9	1		9·2	AC.
124	42·2287	12 10·2	42 34	135 ±	5 ±	1	9·0	12·5	Too faint.
125	42·2370	59·9	42 19	119·1	2·4	2	8·0	10·6	...

	R.A. 1880. h m	Decl. ° ′	P. °	D. ″	Night.	Mags.		Note.
1446	18 38·5	+63 41	21·9	4·9	3	11	12	BC faint.
			53·5	73·1	3		8·0	AB, 14 mag. between.
49	46·2	62 46	135·7	4·7	1	9·5	9·5	...
59	19 13·4	46 58	281·6	4·7	2	8·4	11·5	...
4	30·3	53 38		2·9	2	9·2	10·0	Note.
7	45·8	+60 51	237·7	2·9	3	9·5	9·7	...
3	52·5	+54 3	228 0	7·3	1	8·1	9·0	...
1	20 7·2	+56 36	260·7	5·3	3	8·6	8·7	AB.
			60·7	37·8	3		8·6	AC.
;	8·4	+56 56	129·4	7·8	2	8·5	9·0	...
	43·1	+63 6	264·3	10·4	3	8·5	9·2	...
	50·8	56 43	195·9	6·2	5	7·0	11·2	...
	56·7	56 46	340·6	5·1	1	9·2	9·3	...
	21 16·2	61 21	75·3	2·7	2	8·9	11·5	BC. Note.
			74·5	45·3	3		6·5	AB.
	17·3	60 11	265·2	8·4	2	6·5	12 8	Note.
	17·3	52 52		5 ±	1	9·0	11	...
	34·7	56 26	N.	5·	2	8·5	13·1	Too faint.
	38·0	60 40	186·6	1·9	1	9·5	9·6	...
	48·6	61 30	332·9	7·9	2	8·8	11·2	...
	48·8	61 30	44·9	6·5	2	8·2	13·5	Very difficult.
	50·3	62 3	280·8	19·8	4	7·2	12·8	Aa. Note.
			43·3	22·4	4		12·2	Bb.
			146·1	62·3	3	7·2	7·8	AB (S. 800).
	53·5	62 7	203·0	2·8	5	9·1	9·5	...
)	22 8·1	+52 17	8·4	2·7	1	9·2	9·4	Poor measure.
)	19·9	+54 16	25·1	2·0	3	8·3	10·2	AB.
			204·8	29·1	2		10·2	AC.
	26·7	+61 0	286·2	3·5	2	10	10·5	Note.
ɔ	23 34·3	+63 39	120·9	6·0	2	8·5	8·7	...
8	38·4	+64 23	210·0	3·1	1	9·3	11·0	...

Notes.

Position, October 30, 204°·2; November 7, 225°·1; probably a mistake of 20° in one or other measure.

The measures on both nights of BC were unsatisfactory.

The *comes* is too faint to measure satisfactorily.

S. 800. South speaks of a third star, but he probably refers to one of the more distant *comites*, the two closer ones would probably be too faint for his aperture.

This pair lies 22ˢ·7 f. B.D. + 60°·2403 and 12″·4 S. of it.

Observations of Occultations of Stars by the Moon made at the Royal Observatory, Greenwich, in the Year 1902.

(*Communicated by the Astronomer Royal.*)

Day. 1902.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Jan. 18	Disapp. W. B. (2) II. 1358	Sheepshanks Equat.	150	Dark	5 25 13·38	A. C.
Feb. 12	,, ε Piscium	Great Equat.	670	,,	7 39 22·94	B.
12	,, ,,	Sheepshanks Equat.	150	,,	7 39 22·88	W. B.
12	,, ,,	Great Equat. (Corbett)	120	,,	7 39 22·94	W. H. B.
12	Reapp. ,,	Astrographic Equat.	225	Bright	8 18 11·39	W. S.
13	Disapp. Piazzi I. 223	Old Altazimuth	100	Dark	8 27 53·97	A. C.
13 (*a*)	,, ,,	Sheepshanks Equat.	150	,,	8 27 53·55	W.
13 (*b*)	,, ,,	Astro. Equat. Finder		,,	8 27 52·78	W. S.
13	,, ,,	Astrographic Equat.	225	,,	8 27 53·18	Sti.
15	,, Piazzi III. 215	Sheepshanks Equat.	150	,,	11 26 36·64	A. C.
16	,, ι Tauri	,, ,,	150	,,	6 23 38·10	W.
16	,, ,,	Astro. Equat. Finder		,,	6 23 38·45	W. S.
16	,, ,,	Astrographic Equat.	225	,,	6 23 37·95	Sti.
March 17	,, 26 Geminorum	Sheepshanks Equat.	150	,,	9 18 50·23	A. C.
17	,, ,,	Great Equat. (Corbett)	120	,,	9 18 50·09	R.
17	,, ,,	Great Equat.	670	,,	9 18 49·99	W. B.

Day. 1902.		Phenomenon.		Telescope.	Power.	Limb.	Time of Observation. h m s	Observer.
Mar.	20 (*d*)	Disapp.	ω Leonis 1st Star	Great Equat.	670	Dark	8 27 14·59	B.
	20 (*d*) (*c*)	,,	,,	Sheepshanks Equat.	150	,,	8 27 14·79	W.
	20 (*c*)	,,	,,	Astrographic Equat.	225	,,	8 27 15·35	W. S.
	20	,,	ω Leonis 2nd star	Great Equat.	670	,,	8 27 16·58	B.
	20	,,	,,	Sheepshanks Equat.	150	,,	8 27 16·68	W.
	20	,,	,,	Astrographic Equat.	225	,,	8 27 16·44	W. S.
	22 (*f*) (*g*)	,,	15 Leonis	Sheepshanks Equat.	150	,,	11 (19 6·52)	W. S.
May	12 (*a*) (*h*)	,,	12 Cancri	Old Altazimuth	100	,,	10 37 0·62	R.
	12 (*i*)	,,	,,	Sheepshanks Equat.	150	,,	10 36 58·15	W.
	12 (*j*)	,,	,,	Astrographic Equat.	225	,,	10 36 56·24	W. S.
June	18 (*i*)	,,	Piazzi XVI. 3	,, ,,	225	,,	9 36 15·46	W. S.
	18 (*i*)	,,	ν Scorpii	Sheepshanks Equat.	150	,,	9 37 48·74	G. B.
	18	,,	,,	Astrographic Equat.	225	,,	9 37 48 70	W. S.
Sept.	17 (*f*) (*k*)	,,	21 Piscium	,, ,,	225	,,	11 30 (17·43)	R.
Oct.	16 (*b*) (*l*)	,,	ζ^1 Piscium	Sheepshanks Equat.	150	,,	10 17 18 61	B.
	21 (*f*) (*m*)	Reapp.	W. B. (2) VI. 148	Astrographic Equat.	225	,,	12 12 39 92	W. S.
Dec.	4 (*i*)	Disapp.	β Capricorni	,, ,,	225	,,	7 37 44·74	W. S.

(*a*) The Moon's dark limb was easily visible.
(*b*) The observer noted "perhaps early."
(*c*) The observer suspected the fainter star for a few seconds after this.
(*d*) Instantaneous.
(*e*) The stars could just be separated before disappearance.
(*f*) These observations being uncertain have not been used.
(*g*) The signal for comparison of clocks failed to register.
(*h*) The star faded gradually.
(*i*) The star was diffused.

(*j*) This was not considered a good observation.
(*k*) The limb was boiling; the star was probably not really occulted so soon.
(*l*) The limb was almost full; the star apparently entered a deep cleft in the limb.
(*m*) Thin cloud over the Moon. The star was faint. The observer was not certain whether the star appeared from behind the Moon or the cloud.

The apertures of the telescopes used are as follows :—

	inches.		inches.
Great Equatorial	28	Great Equatorial (Corbett Telescope) ...	$6\frac{1}{2}$
Astrographic Equatorial (Guiding Telescope)	10	Old Altazimuth	4
Sheepshanks Equatorial	$6\frac{3}{4}$	Astrographic Equatorial Finder	$2\frac{1}{2}$

The initials A. C., B., R., W. B., W., G. B., W. S., W. H. B., Sti., are those of Mr. Crommelin, Mr. Bryant, Mr. Rendell, Mr. Bowyer, Mr. Witchell, Mr. Bischlager, Mr. Stevens, Mr. Brookes, and Mr. Stiles respectively.

Royal Observatory, Greenwich: 1903 *January* 9.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXIII. FEBRUARY 13, 1903. No. 4.

ANNUAL GENERAL MEETING.

E. B. KNOBEL, Esq., VICE-PRESIDENT, in the Chair.

The Report of the Auditors of the Treasurer's accounts for the year 1902 was read, and is given on p. 182.

The Annual Report of the Council was read; see pp. 179 to 180.

The Address was delivered by Professor H. H. Turner, D.Sc., F.R.S., after which the Gold Medal was handed to Count von Bernstorff, the Councillor of the German Legation, for transmission to Professor Hermann Struve, to whom the Medal had been awarded for his work on the Satellites of *Saturn*.

The following alteration of Bye-Law 23, which had been proposed by the Council, was brought forward by the Treasurer:

That the Composition fee be raised to thirty guineas, and be reduced by one guinea each year after five years to a minimum of five guineas, and that Bye-Law 23 be altered accordingly.

After a discussion the motion was put to the meeting and carried, the Bye-Law as altered reading as follows:

23. Any Fellow may, at his entrance, compound for his contributions by the payment of thirty guineas, exclusive of his admission fee; or he may at any time afterwards in the ensuing five years (all sums then due being first paid) compound for his *subsequent* annual contributions by a like payment of thirty guineas. After the first five years the Composition fee will be reduced by one guinea for each year of Fellowship in excess of five years, to a minimum fee of five guineas, under the same conditions.

The Society then proceeded to the ballot for Officers and Council for the ensuing year, the names of those elected being given on p. 291.

The thanks of the Meeting were given to the retiring Members of Council and also to the Auditors of the Treasurer's Accounts and the Scrutineers of the Ballot.

Thomas Ayres, M.Sc. (Vict.), Finkmattstrasse 7, Strassburg, Germany;
Charles William Keighley, Cluny Villa, Burlington Lane, Chiswick; and
Henry Norris Russell, Oyster Bay, New York, U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Thomas Frederick Bowers, B.A., Head Master, Woolwich Polytechnic School, and "Darenth," Little Heath, Old Charlton, S.E. (proposed by J. E. Evans);
Frederick Hugh Capron, solicitor, "Polaris," 38 Avenue Road, Highgate N. (proposed by the Rev. P. H. Kempthorne);
Kenneth Essex Edgeworth, Lieut. R.E., Stanhope Lines, Aldershot (proposed by W. E. Wilson);
Alphonso King, Elementary Teacher, 93 Victoria Road East, Leicester (proposed by Walter E. Besley);
William Tillar, Board of Trade Surveyor, St. Kilda's, Westbourne Road, West Kirby (proposed by M. J. O'Sullivan);
Gilbert Thomas Walker, Assistant Reporter in Meteorology to the Government of India, Trinity College, Cambridge, (proposed by H. H. Turner); and
Pollard Wilkinson, B.A., B.Sc. (Lond.), Schoolmaster, 21 Ashmere Grove, Ipswich (proposed by Alfred H. Fison).

Report of the Council to the Eighty-Third Annual General Meeting of the Society.

The following table shows the progress and present state of Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
01 December 31	250	375	625	46	1	672
ace elected	+ 5	+ 31	...	...	...	...
ceased	...	− 10	...	− 2	...	...
signed	...	− 11	...	...	...	...
movals	+ 2	− 2	...	...	...	...
pelled	...	...	...	...	...	...
02 December 31	257	383	640	44	1	685

Mr. Maw's Account as Treasurer of the Royal

RECEIPTS.

	£ s. d.	£ s. d.
Balances, 1902 January 1:—		
At Bankers', as per Pass-book	101 8 4	
„ on deposit	300 0 0	
In hand of Assistant Secretary on account of Turnor and Horrox Fund...	6 9 3	
		407 17 7
Dividends on £1,250 Metropolitan 3-per-cent. Stock	35 4 1	
Dividends on £932 19 0 Metropolitan 2½-per-cent. Stock	21 17 10	
Dividends on £3,400 East Indian Railway 3-per-cent. Debenture Stock	95 14 6	
Dividends on £3,200 London and North-Western Railway 3-per-cent. Debenture Stock	90 6 0	
Dividends on £4,000 Midland Railway 2½-per-cent. Debenture Stock	94 1 3	
Dividends on £1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock	52 9 8	
Dividends on £1,100 Commercial Gas Co. 4½-per-cent. Debenture Stock	46 9 2	
Interest on £300 on Deposit at Bankers'	5 9 8	
		441 12 2
Received on account of Subscriptions:—		
Arrears	130 4 0	
Annual Contributions for 1902	604 16 0	
„ „ 1903	4 4 0	
Admission Fees	73 10 0	
First Contributions	49 7 0	
		862 1 0
Composition Fees		147 0 0
Sales of Publications:—		
At Williams and Norgate's, 1901	13 16 4	
At Society's Rooms, 1902	52 1 2	
Sales of Photographs, 1902	17 14 6	
		83 12 0
Received from Mr. H. C. Russell towards cost of reproducing plates in *Monthly Notices* ...		3 0 0
Income Tax refunded by Commissioners of Inland Revenue		26 8 9
Cheques outstanding 1902 December 31		16 19 6
Due to Assistant Secretary on Petty Cash Account	1 17 2	
„ „ on account of Turnor and Horrox Fund	0 4 7	
		2 1 9
		£1,990 12 9

Examined and found correct, 1903 Jan. 8:
H. P. Hollis, F. W. Levander, W. J. S. Lockyer.

xal Society, from 1902 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
retary: Salary	250	0	0			
„ for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
... ...	2	12	6			
ce	9	9	6			
				12	2	0
tes, &c., *Monthly Notices* (Spottiswoode	455	5	5			
ring Plates in *Monthly Notices* (Dent	5	8	9			
emoirs (Adams MSS.) (Dent & Co.) ...	31	10	0			
., Appendix to *Memoirs* (Harrison &	61	2	0			
ppendix to *Memoirs* (London Stereo- o.)	14	7	6			
pendix to *Monthly Notices* (Harrison ons)	19	12	6			
ist of Fellows and Miscellaneous ottiswoode & Co.)	24	16	6			
				612	2	8
of Ephemerides in *Monthly Notices* ...				15	0	0
Horrox Funds: Purchases for Library	21	13	10			
ts in Library	47	2	9			
				68	16	7
of Photographs				16	0	2
astronomical literature for the Inter- Catalogue of Scientific Literature ...				30	0	0
s	52	0	0			
Telegrams	71	15	9			
Parcels, &c.	4	17	2			
pottiswoode & Co.)	4	9	6			
onery and Office Expenses	6	14	9			
				139	17	2
Meetings	19	8	0			
enses	10	12	0			
&c.	5	0	0			
				35	0	0
ises	63	0	11			
s	58	10	11			
it Expenses	6	6	4			
irs, Fittings, &c.	22	16	8			
... ...	5	14	4			
				156	9	2
&c., Addresses to Glasgow University ons College, Manchester	5	16	0			
to cost of illuminating, &c., the front ngton House, 1902 August 9	15	0	0			
				20	16	0
lt Gift to Dr. T. D. Anderson ...				25	0	0
n Cheques, &c....					3	0
o Assistant Secretary of amount due c. 31 on Petty Cash Account... ...				1	19	3
tanding, 1901 Dec. 31				16	19	6
02 December 31 :— ters', as per Pass-book	231	16	9			
Cheque not credited till 1903 ...	8	10	6			
ters', on deposit	300	0	0			
				540	7	3
				£1,990	12	9

Report of the Auditors.

We have examined the Treasurer's accounts of receipts and expenditure for the year 1902, and have found and certified the same to be correct. The cash in hand on December 31, 1902, including the balance at the bankers', &c., amounted to 540*l.* 7*s.* 3*d.*

The invested property of the Society is the same as at the end of the previous year.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

We wish to repeat our recommendation of last year that the amount of the composition fee should be increased, and we suggest further that the number of annual contributions previously paid should be taken into account in fixing the amount in the case of the present Fellows.

We think that, as a matter of account, the amount received for composition fees should not appear as annual income, but that a Capital Account should be kept in which these amounts should be exhibited.

(*Signed*) H. P. Hollis.
F. W. Levander.
W. J. S. Lockyer.

1903 *January* 8.

Trust Funds.

The Turnor Fund: A sum of £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given by the Council to the widow or orphan of any deceased Fellow of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1903 January 1.

	£	s.	d.	£	s.	d.
Balances, 1902 December 31:—						
At Bankers', as per Pass-book	231	16	9			
Cheque not credited till 1903	8	10	6			
At Bankers' on deposit	300	0	0			
	540	7	3			
Less due to Assistant Secretary on Petty Cash Account and Turnor and Horrox Fund Accounts £2 1 9						
Less Cheques outstanding ... 16 19 6						
	19	1	3			
				521	6	0
Due on account of Subscriptions:—						
3 Contributions of 4 years' standing	25	4	0			
7 ,, 3 ,, ...	44	2	0			
28 ,, 2 ,, ...	117	12	0			
64 ,, 1 ,, ...	134	8	0			
1 Admission Fee and First Contributions ...	3	3	0			
	324	9	0			
Less 2 Contributions paid in advance ...	4	4	0			
				320	5	0
Due for Photographs sold				0	13	0
Due from Messrs. Williams and Norgate for sales of Publications during 1902				7	13	11

£3,400 East Indian Railway 3-per-cent. Debenture Stock, including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (née Gwilt) Fund.

£3,200 London and North Western Railway 3-per-cent. Debenture Stock.

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£1,100 Commercial Gas Company 4½-per-cent. Debenture Stock.

£1,250 Metropolitan 3-per-cent. Stock.

£932 19 0 Metropolitan 2½-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Four Gold Medals.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	8	...	XXXI.	113	...
I. Part 2	42	...	XXXII.	125	...
II. Part 1	51	3	XXXIII.	133	...
II. Part 2	16	3	XXXIV.	136	...
III. Part 1	65	1	XXXV.	83	...
III. Part 2	82	1	XXXVI.	165	8
IV. Part 1	77	3	XXXVII. Part 1	310	7
IV. Part 2	89	3	XXXVII. Part 2	258	8
V.	72	3	XXXVIII.	244	1
VI.	90	6	XXXIX. Part 1	209	2
VII.	112	3	XXXIX. Part 2	212	2
VIII.	97	3	XL.	224	1
IX.	102	3	XLI.	365	1
X.	115	...	XLII.	207	3
XI.	120	...	XLIII.	203	...
XII.	124	...	XLIV.	186	1
XIII.	120	...	XLV.	219	...
XIV.	330	...	XLVI.	195	2
XV.	105	...	XLVII. Part 1	2	...
XVI.	130	1	XLVII. Part 2	18	...
XVII.	117	1	XLVII. Part 3	2	...
XVIII.	109	1	XLVII. Part 4	8	...
XIX.	119	...	XLVII. Part 5	8	...
XX.	109	1	XLVII. Part 6	9	...
XXI. Part 1	244	...	XLVII.	190	1
XXI. Part 2	98	...	XLVIII. Pt. 1	222	1
XXI.	31	...	XLVIII. Pt. 2	223	1
XXII.	131	...	XLIX. Part 1	348	2
XXIII.	116	...	XLIX. Part 2	234	2
XXIV.	126	1	L.	221	2
XXV.	129	...	LI.	248	...
XXVI.	139	1	LII.	283	2
XXVII.	394	1	LIII.	290	2
XXVIII.	351	...	LIV. App. I.	582	...
XXIX.	374	1	App. II.	622	...
XXX.	126	1	App. III.	684	...
			Index to *Memoirs*	607	2

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	52	...	XXXIII.	86	...
II.	54	...	XXXIV.	65	1
III.	...	...	XXXV.	51	...
IV.	...	...	XXXVI.	25	1
V.	...	...	XXXVII.	31	3
VI.	39	...	XXXVIII.	95	2
VII.	2	...	XXXIX.	95	...
VIII.	150	1	XL.	103	3
IX.	23	3	XLI.	103	5
X.	170	1	XLII.	111	1
XI.	181	...	XLIII.	108	2
XII.	104	1	XLIV.	110	2
XIII.	176	2	XLV.	114	1
XIV.	175	3	XLVI.	107	...
XV.	167	2	XLVII.	122	2
XVI.	152	1	XLVIII.	117	...
XVII.	164	...	XLIX.	108	7
XVIII.	241	...	L.	108	9
XIX.	51	...	LI.	110	6
XX.	31	...	LII.	106	10
XXI.	16	...	LIII.	110	13
XXII.	30	...	LIV.	108	13
XXIII.	17	...	LV.	121	...
XXIV.	22	...	LVI.	119	2
XXV.	13	...	LVII.	125	2
XXVI.	9	...	LVIII.	122	...
XXVII.	3	...	LIX.	128	2
XXVIII.	70	...	LX.	132	3
XXIX.	50	...	LXI.	131	6
XXX.	61	2	LXII.	137	8
XXXI.	90	...	1st Index ...	540	1
XXXII.	106	5	2nd „ ...	788	...
Library Catalogue				538	2
„ „ Supplement				420	...

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly

all the volumes. With the exception, however, of Vols. XXX to LXII., no complete volumes can be formed from the sepa numbers in stock.

Celestial Photographs.

The following is a list of reproductions of Celestial Ph graphs published by the Royal Astronomical Society for sale the Fellows :—

R.A.S. Ref. No.	Subject.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*	Isaac Roberts
5	Nebula M 74 *Piscium* (N.G.C. 628)	Isaac Roberts
6	Great Nebula in *Orion*	Isaac Roberts
7	Milky Way near M 11	E. E. Barnard
8	Milky Way near Cluster in *Perseus*	E. E. Barnard
9	Comet *c* 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet *a* 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about η *Argûs*	David Gill
12	Portion of Moon (Hyginus-Albategnius)	Lœwy and Puiseux
13	Comet *c* 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet *c* 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet *c* 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet *a* 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet *f* 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet *a* 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	Lœwy and Puiseux
20	Nebula in *Andromeda*	Isaac Roberts
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis* (N.G.C. 6205)	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age $7^d\ 3^h$)	Lick Observatory
26	The Moon (Age $12^d\ 6\frac{1}{2}^h$)	Lick Observatory
27	The Moon (Age $16^d\ 18^h$)	Lick Observatory
28	The Moon (Age $23^d\ 8^h$)	Lick Observatory

R.A.S. Ref. No.	Subject.	Photographed by
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of Maginus)	Lœwy and Puiseux
32	The Moon (Age $14^d\ 1^h$)	Lick Observatory
33	Portion of Moon (Ptolemæus, &c.)	Lick Observatory
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ* (N.G.C. 6779)	
42	Nebulæ M 81, 82 *Ursæ Majoris* (N.G.C. 3031, 3034)	
43	Cluster M 56 *Lyræ* (enlarged) (N.G.C. 6779)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*	W. E. Wilson
57	Dumb-bell Nebula, *Vulpeculæ* (N.G.C. 6853)	W. E. Wilson
58	Spiral Nebula, *Canes Venatici* (N.G.C 5194)	W. E. Wilson
59	Ditto (enlarged) (N.G.C. 5194)	W. E. Wilson
60	Annular Nebula, *Lyra* (N.G.C. 6720)	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*	Roy. Obs., Greenwich
67	Spectrum of Sun's limb, 1898 January 22	E. H. Hills

R.A.S. Ref. No.	Subject.	Photographed by
68	Annular Nebula, *Lyræ* (N.G.C. 6720)	Lick Observatory
69	Dumb-bell Nebula, *Vulpeculæ* (N.G.C. 6853)	Lick Observatory
70	Spiral Nebula, *Canes Venatici* (N.G.C. 5194-5)	Lick Observatory
71	Spiral Nebula, *Ursæ Majoris* (N.G.C. 5457)	Lick Observatory
72	Trifid Nebula, *Sagittarius* (N.G.C. 6514)	Lick Observatory
73	Great Nebula in *Orion*	Lick Observatory
74	Cluster M 13 *Herculis* (N.G.C. 6205)	Lick Observatory
75	Solar Surface with Faculæ	G. E. Hale
76	Faculæ and Prominences	G. E. Hale
77	Total Solar Eclipse, 1898 Jan. 22 (½ sec.)	W. H. M. Christie
78	Nebula H V. 14 *Cygni* (N.G.C. 6992)	W. E. Wilson
79	Portion of Moon (Theophilus, &c.)	Yerkes Observatory
80	Total Solar Eclipse, 1900 May 28 (30 sec.)	E. E. Barnard
81	Comet 1901 I., 1901 May 4	Roy. Obs., Cape of G. H.
82	Comet 1901 I., 1901 May 6	Roy. Obs., Cape of G. H.
83	Comet 1901 I., 1901 May 9	Perth Obs., W. Australia
84	Solar Surface with Faculæ	H. Deslandres
85	Solar Prominences	H. Deslandres
86	Nebula about Nova *Persei*, 1901 September 20	G. W. Ritchey
87	Nebula about Nova *Persei*, 1901 November 13	G. W. Ritchey
88	Total Solar Eclipse, 1901 May 18 (10 sec.)	F. W. Dyson
89	Total Solar Eclipse, 1901 May 18 (40 sec.)	F. W. Dyson

Nos. 44–55 and Nos. 64 and 65 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches, and also as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, 6¼ inches square.

Price of prints, 1*s.* 6*d.* each; lantern slides, 1*s.* each; packing and postage extra.

Unmounted prints, 1*s.* each, can be obtained to order.

Transparencies, 6¼ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, xxxvi. p. 126.

1. The *Harrison* clock.
2. The *Owen* portable circles, by Jones.
3. The *Beaufoy* circle.
4. The *Beaufoy* transit instrument.
5. The *Herschel* 7-foot telescope.
6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
7. The *Smeaton* equatorial.
8. The *Cavendish* apparatus.
9. The 7-foot Gregorian telescope (late Mr. Shearman's).
10. The variation transit instrument (late Mr. Shearman's).
11. The universal quadrat, by Abraham Sharp.
12. The *Fuller* theodolite.
13. The standard scale, by Troughton and Simms.
14. The *Beaufoy* clock, No. 1.
15. The *Beaufoy* clock, No. 2.
16. The *Wollaston* telescope.
17. The *Lee* circle.
18. The *Sharpe* reflecting circle.
19. The *Brisbane* circle.
20. The *Baker* universal equatorial.
21. The *Reade* transit.
22. The *Matthew* equatorial, by Cooke.
23. The *Matthew* transit instrument.
24. The *South* transit instrument.
25. A sextant, by Bird (formerly belonging to Captain Cook).
26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

No. 31. (5) 2¾-inch achromatic telescope of 28¼-inch focal length, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, 2¾-inch aperture and 45 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, 2¼-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass 1⅝-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass 1¾-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

No. 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.
„ 47. (21) Box sextant; reflecting plane and level.
„ 48. (22) Prismatic compass, by Troughton and Simms.
„ 49. (23) Mountain barometer.
„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
„ 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.

No. 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. 3½-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watch-case, by Professor Chevallier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. Two old sun-dials.
„ 118. A 10½-inch sixteenth-century celestial globe, on bronze tripod stand.
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.

No. 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant with counterpoise stand, by. Troughton.
„ 131. Double box sextant, by Cary.
„ 132. Equatorially mounted camera with 2½-inch portrait lens and telephotographic enlarging lens by Dallmeyer; iron pillar.
„ 133. 3¼-inch equatorial by Ross, with tall tripod stand, equatorial mounting, eyepieces, and micrometer.
„ 134. Old transit instrument, 2-inch aperture and 3 feet focal length (without stand), formerly belonging to Dr. Longfield, of Cork.
„ 135. Globe of Mars, by E. M. Antoniadi.
„ 136. A small universal instrument by W. and S. Jones, London; the telescope 1½-inch aperture and 15 inches focal length. [Presented by Miss Moore.]
„ 137. Polar siderostat by Hilger, with 4⅛-inch mirrors. [Presented by Mr. Alexr. Foote.]
„ 138. Transit instrument, aperture 2¾-inch, with collimator and stand. [Presented by Mrs. Cross.]
„ 139. Transit instrument, aperture 1 11/12-inch, with portable stand. [Presented by Mrs. Cross.]
„ 140. 3½-inch object-glass and tube. [Presented by Mrs. Cross.]
„ 141. 9-inch Newtonian reflector and equatorial stand. [Presented by Mrs. Cross.]

Besides the above, there is the following apparatus available for eclipse work:—

4 Slits for spectroscope.
Abney doublet lens used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 22. The *Matthew* equatorial, to Mr. C. Thwaites.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.
„ 30. (4) 3¼-inch equatorial and stand, to Mr. M. E. J. Gheury.
„ „ Double-image micrometer, to the Rev. W. J. B. Roome.
„ 31. (5) 2¾-inch telescope (object-glass only), to the Rev. C. D. P. Davies.
„ 37. (11) Zenith telescope (object-glass only), to the Rev. C. D. P. Davies.
„ 57. (31) Box sextant, to Dr. A. A. Common.
„ 69. (43) Telescope with rock-crystal object-glass, to Sir W. Huggins.
„ 98. 2-foot 6-inch navy telescope, to the Rev. J. M. Bacon.
„ 123. 6-inch telescope, by Grubb (object-glass only), to Mr. W. H. Wilson.
„ 125. 6-inch refractor, by Simms, to Dr. A. A. Common.
„ 126. 3½-inch portable telescope by Tulley, to Mr. J. H. Bell.
„ 130. 10-inch pillar sextant, to Mr. F. Robbins.
„ 133. 3¼-inch equatorial, by Ross, to Dr. A. W. Roberts.
„ 139. Transit instrument and stand, to the Rev. C. L. Tweedale.
„ 140. 3½-inch object-glass and tube, to the Rev. C. L. Tweedale.

Award of the Gold Medal.

The Council have awarded the Society's Gold Medal to Professor Hermann Struve for his work on the satellites of *Saturn*. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

During the past year vol. lxii. of the *Monthly Notices* has been issued.

In accordance with the arrangement made with the Royal Society, mentioned in last year's Annual Report, two Appendices to vol. lxii. were issued, containing the preliminary reports on the Observations of the Total Solar Eclipse of 1901 May 18, and other papers.

Appendix III. to vol. liv. of the *Memoirs* has also been published, containing Sir Norman Lockyer's account of the observations of the total Solar Eclipse of 1900 May 28, made at Santa Pola, Spain.

It is hoped that vol. liv. of the *Memoirs* will appear in the course of the present year.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—* J. J. Aubertin.
† John Brett.
Rev. S. B. Burnaby.
Col. E. H. Cooper.
P. F. Duke.
‡ Commander E. J. Griffin.
Arthur Kennedy.
A. O. Hilger.
G. D. Lardner.
Rev. Thomas Wiltshire.
Associates :—Marie Alfred Cornu.
Hervé Faye.

John James Aubertin was born in 1818, being the fourth son of the Rev. Peter Aubertin, Rector of Chipstead, Surrey. Much of his life was spent in travel, and he published several works on his experiences in Mexico, South Africa, &c. He observed the total solar eclipse of 1870 at Gibraltar, and in 1893 made the journey to Chile to observe the eclipse on the 16th of April of that year. He joined Professor Schaeberle's party at Mina Bronces, and after observing the eclipse travelled through Peru, visiting the Arequipa Observatory. He wrote a popular account of his travels and observations, entitled *By Order of the Sun*.

Mr. Aubertin was a Spanish and Portuguese scholar, and published a translation of the great Portuguese epic of Camoens, the *Lusiad*, and seventy of his sonnets.

He was elected a Fellow of the Society on the 11th of January 1895, and died at Weymouth on the 24th of August 1900.

Sherrard Beaumont Burnaby was born at Doctors' Commons, London, on the 2nd of November 1831. His father died when the son was a boy, and the latter was placed under the

* Died in 1900, but death not reported till 1902.
† Obituary given in last Annual Report.
‡ Died in 1901, but death not reported till 1902.

guardianship of the Vicar-General, Dr. S. B. Burnaby. Mr. Burnaby was educated at St. Paul's School, from which he passed to Christ's College, Cambridge, where he was a contemporary of Sir Walter Besant. He was ordained deacon in 1857 and priest in 1859; and from 1857 to 1864 was curate of Holy Trinity, Stepney. His health having broken down he left Stepney, and was for a time chaplain to Earl Fortescue. In 1866 he was appointed Rector of Wapping, and while there took the chief part in arranging hospital accommodation, &c., during an epidemic of cholera, subsequently becoming a sufferer himself. In 1871 Mr. Burnaby married, and in 1873 was appointed Vicar of Hampstead, where he remained till 1900, when he was compelled to resign his living, much to the regret of his parishioners, owing to a serious affection of the vocal chords. In November 1899 he had undergone a serious operation from which he never really recovered.

Mr. Burnaby was greatly interested in questions concerning chronology and the calendar, and had in hand a comprehensive work on various calendars and eras. Less than a year before his death he published a treatise on the Jewish and Muhammadan Calendars, dealing very fully with the intricacies of the subject, simplifying and correcting the rules for both calendars, giving explanations for the rules and Chronological Tables.

He was elected a Fellow of the Society on the 9th of April 1897; he died at Great Missenden, Bucks, on the 23rd of February 1902, leaving three sons living.

The Right Honourable Edward H. Cooper was born in 1827 in Westmeath, and died at 42 Portman Square, London, on the 26th of February 1902. He entered the army and held commissions successively in the 7th Hussars, 72nd Seaforth Highlanders, and the Grenadier Guards. He retired in 1865, and for the years 1867–69 represented Sligo in the House of Commons. From 1877 Colonel Cooper was Lieutenant and Custos Rotulorum for County Sligo. He was made Privy Councillor for Ireland in 1899. Colonel Cooper succeeded to Markree Castle at the death of his uncle, Mr. E. J. Cooper, in 1872. Mr. Cooper had established there what was at its erection one of the finest private observatories, with an excellent transit circle, and the largest refractor in the world with the exception of those at Pulkowa and Washington. With his assistant, Mr. Graham, he made many observations of minor planets, and very extensive observations of zodiacal stars. Colonel Cooper had not his uncle's interest in astronomy, but was interested in meteorology. He had meteorological observations regularly made and reported, and Markree was one of the best meteorological stations in Ireland. In 1876 Colonel Cooper appointed in charge of the observatory Dr. Doberck, who made observations of double stars. Reports of the observatory were given each year from 1876–1883. In 1883 Mr. Marth succeeded Dr. Doberck. He

carried out the meteorological observations, but made no astronomical ones, devoting his spare time to the construction of ephemerides for physical observation of the Moon and planets. Mr. Henkel was appointed as Marth's successor in 1898, and remained in charge of the observatory till Colonel Cooper's death. Colonel Cooper married in 1858 Charlotte Maria Mills, and had several children, the eldest of whom died in South Africa in 1900.

Colonel Cooper was elected a Fellow of the Society in 1872.

Edward John Griffin was born in Dublin on the 19th of September 1848, and was educated at the Merchant Taylors' School. He entered the Mercantile Marine, and served as junior officer in the transport *Kingston* during the Abyssinian war in 1868–9. In January 1878 he joined the Union Steam Ship Company, and in 1879 was given the command of the *Danube* of that line. In 1884 he commanded the *Anglian*, which conveyed the troops to Egypt, and in 1885 of the *Arab*, which was the head-quarter ship of the transport staff at Suakim. For his services ashore and afloat he was awarded the "Egyptian Medal," the "Khedive's Bronze Star," and the "Suakim 1885 Clasp." At the conclusion of the war he conveyed the Australian Contingent back to Sydney, and received from the Government of New South Wales appreciative recognition for his services.

In 1887 he was elected a Younger Brother of the Trinity House. He reached the rank of commander in the Royal Naval Reserve in 1896. In 1898 he was placed in command of the R.M.S. *Briton*, the largest vessel of the Union Steam Ship fleet, and remained in her until his death on the 7th of July 1901.

Commander Griffin married at the Cape in 1878, and leaves a widow and six children.

He was elected a Fellow of the Society on the 14th of January 1898.

Arthur Kennedy was born at Balham in 1852, and was the son of Mr. Thomas Kennedy, of Balham and Chancery Lane, solicitor. He was sent to school at Brighton, and later to the Lycée at Orleans. At the age of sixteen he was articled to his father, becoming in 1874 a partner in the firm of Kennedy, Hughes, and Kennedy, and eventually senior partner.

Mr. Kennedy did no original work in astronomy, but throughout his life had a keen interest in astronomical studies. He devoted much of his leisure time to observing, and delighted his friends at Epsom by astronomical lectures in his own house. He was elected a Fellow of the Society on the 13th of March 1891, and was a constant attendant at the meetings. He joined the British Astronomical Association soon afterwards, and served on its Council from 1896 to 1901, and took a constant and deep interest in the welfare and progress of that Society.

Mr. Kennedy married in 1887, and leaves three daughters.

His death took place under exceptionally sad circumstances, as he was accidentally drowned at Bacton-on-Sea on the 14th of August 1902. He will be remembered by a large circle of friends, who admired his professional ability and appreciated his kindly and unselfish character.

Otto Hilger was born in Darmstadt on the 20th of January 1850, and when quite a young boy was apprenticed to his father, who was Master of the Mint in that city. After finishing his apprenticeship he went to Frankfort and worked as a mechanical engineer with his elder brother Adam. In 1868 the two Hilgers went to Paris, where they started a workshop and obtained work for the Observatory. Being German subjects, they were obliged to leave Paris at the outbreak of the Franco-Prussian war. They came to London, and Adam Hilger became foreman with Mr. John Browning, Otto being employed by the same firm. Five years later Adam Hilger commenced business on his own account as astronomical and optical instrument maker, and took his brother into his employment. In 1888 Otto Hilger was appointed by Lord Blythswood to take charge of his private laboratory, where, under Lord Blythswood's directions, he was engaged in constructing an engine for ruling gratings, when he was compelled, in 1897, on the death of his brother, to return to London and take charge of the business.

Mr. Hilger died on December 18. He leaves a widow and three children.

He was elected a Fellow of the Society on the 8th of February 1901.

George Darley Lardner, second son of the Rev. Dionysius Lardner, LL.D., D.C.L., F.R.S., by his first wife, Cecilia Flood, was born in Dublin on the 21st of August 1818. Dr. Dionysius Lardner probably did more than any other man in the first half of the nineteenth century to advance the cause of education. His high mathematical attainments, combined with the unusual lucidity and ability with which he explained applied mathematics and mechanics, gave him a power in education which has seldom been equalled in that branch of knowledge. But his genius was versatile ; all knowledge fascinated him, and, not content with writing many valuable works on various scientific subjects, he produced his celebrated *Cabinet Encyclopædia* in 133 volumes, in which he was assisted by the most prominent men of the time in literature and science.

So brief a reference to his distinguished father is due because George Darley inherited many of his gifts, but none of his ambitions. If he had not read very high mathematics, he had mastered sufficient to enable him to take great interest in astronomy, and was able to explain phenomena in clear and simple language. He had even a greater love than his father had for general literature. Possessing a good memory and a

knowledge of both French and German, he was a fund of information to his friends and the most charming companion, a good conversationalist, and no mean "raconteur." The most unassuming of men and lacking his father's ambition, his great abilities were reserved for his official duties and for those who knew him, or whom he could benefit by them.

Educated first at a school at Epsom, Surrey, he went to Paris, where he studied for the medical profession in the French University. While in Paris he was offered a commission in the Commissariat Department of the British army. Having no predilection for the medical profession, he readily accepted it, and was sent to the Cape of Good Hope, where he served on the frontier. From the Cape he went to New Zealand and took part in the first Maori war, receiving the medal. He married at Auckland, New Zealand, in 1841, and returned home some years later. He served in Ireland, and then for many years in the West Indies and Honduras, and, during his last appointment at Barbados in the sixties, was head of his department in the Windward and Leeward Islands. He again served in Ireland during the Fenian troubles of 1865 and 1866, and he retired on a pension after thirty years' service, in 1868. After his retirement from the army Commissary-General Lardner occupied his leisure in literary and scientific pursuits, and was never happier than when he was engaged in preparing for and delivering to juvenile audiences lectures on astronomy and physics. He compiled and printed for private circulation a text-book on elementary astronomy. Both mentally and physically he was in full activity when he was suddenly called away without illness on the 14th of January 1902, in his eighty-fourth year. He was elected a Fellow of the Society on the 8th of February 1895. By his first wife, Mary Macintosh, who died in 1870, he had two children, who both survive—William George Lardner, of Hove, Sussex, and Mary Ann, married to Colonel R. H. Vetch, C.B., R.E. His second wife, Emily D. Clarke, is also living.

[For the above particulars the Council is indebted to Colonel R. H. Vetch.]

The Rev. Thos. Wiltshire, M.A., D.Sc., &c., was born in London on the 21st of April 1826, and was through his mother a descendant of the ancient family of Pomeroy of Berry Pomeroy, in Devonshire. As he was a delicate child he was never sent to school, but educated by a tutor at home until he was of an age to attend King's College, whence in due course he proceeded to Trinity College, Cambridge, where in 1850 he graduated as Senior Optime. He was ordained deacon in the same year by the Bishop of Rochester, and subsequently priest by the Bishop of London in 1853. He held his first curacy at Riddings, in Derbyshire. Being prohibited by his medical attendant from living in a climate obviously unsuited to him, he came to London, and for

some years resided at Brompton. He then did occasional Sunday duty at various churches, and ultimately Dr. Kynaston, the Rector of St. Nicholas Cole Abbey, gave him the Rectory House (afterwards demolished in making Queen Victoria Street) on condition that he would look after the parish generally. Thus for some years he lived in the very heart of the City of London. Another civic appointment he obtained in the shape of the Evening Lectureship at St. Clement's, Eastcheap. This dies with him. From his youth he took a keen and abiding interest in geology, and joined the staff of King's College as Lecturer in Geology in 1872. In 1881 he was appointed Assistant Professor, and was Professor from 1890 to 1897. He sat for many years on the Council of the Geological Society, of which until quite recently he was Treasurer. He was for many years, too, Honorary Secretary to the Palæontographical and Ray Societies, the members of which united in 1890 in presenting him with his portrait and a testimonial. This portrait now hangs in the "Wiltshire" collection of fossils in the Woodwardian Museum at Cambridge, to which he was a benefactor, having presented his old University with his splendid collection of fossils, and founded a "Wiltshire" prize for proficiency in geology and mineralogy. In recognition of this the honorary degree of D.Sc. was conferred on him on April 27, 1899. He was a member of the Clothworkers' Company, and at one time Master, an office held by Samuel Pepys in the reign of Charles the Second, and by Lord Kelvin quite recently. In this connection he also founded prizes in the Company's Grammar School at Sutton Valence, in Kent. He was also on the Executive Committee of the City and Guilds of London Institute, and on the Council of the Yorkshire College, King's College, &c., and was a member of the Athenæum Club. His interest in astronomy was purely in its mathematical aspect, as at no time was he ever a practical observer. It is some years since he attended any of our meetings. On the night of the 26th of October last he went up to London from his residence at Blackheath, and preached his usual sermon as evening lecturer at St. Clement's, Eastcheap, returning apparently in perfect health, but early the next morning died in his sleep, without a struggle, from heart failure. He was elected a Fellow of this Society on the 9th of March 1860.

Marie Alfred Cornu was born on the 6th of March 1841 at Châteauneuf, near Orleans.

He was sent to the Lycée at Orleans, and in 1860 entered the École Polytechnique, and two years later the École des Mines. He finished his course here in 1866, and the next year, at the age of 26, he was chosen as Professor of Physics at the École Polytechnique.

His earliest researches, communicated to the Académie des Sciences in 1863-65, were on "The Reflection of Light at Metallic Surfaces" and kindred subjects. Soon after this he

commenced his researches on "The Velocity of Light," and devised various improvements on Fizeau's method, which he tested by observations between the École Polytechnique and Mont Valérien, stations about 6½ miles apart. The desirability of a redetermination of the velocity of light with all attainable accuracy was brought into prominence by its relation to the solar parallax, which was then occupying the thoughts of astronomers in connection with the approaching transits of *Venus*. Early in 1874, at the suggestion of Le Verrier and Fizeau, the Council of the Observatory of Paris asked Cornu to make this redetermination.

He chose the terrace of the Observatory as one station, and erected on it a telescope of 15 inches aperture and 30 feet focus to transmit a beam of light to a mirror mounted on the tower of Montlhéry, about 14 miles distant, which reflected the light back to him. The toothed wheel by which he measured the time of transmission to Montlhéry and back was capable of 1600 revolutions per minute, and he was able with this apparatus to obtain a movement of as many as twenty-one teeth of the wheel during the passage and repassage of the beam of light. As a mean of many experiments he found for the velocity of light *in vacuo* 186,700 miles per second, which it may be interesting to note gives, in combination with the value 20″·52 for the constant of aberration, a value of 8″·77 for the solar parallax. An interesting account of Cornu's method and results is given in *Nature*, 4th of February 1875.

In conjunction with M. Baille, Cornu, between 1870 and 1880, made several determinations of the mean density of the Earth. They used the method of the torsion balance designed by Michell, and first employed by Cavendish, commencing their work by careful subsidiary studies of the torsion balance. Their apparatus, which was set up in a cellar of the École Polytechnique, differed from that used by their predecessors in several particulars, especially in the employment of much smaller attracting masses, and in the use of hollow spheres filled with mercury, which could be pumped from a sphere on one side to another on the other side, thus avoiding the disturbance caused by the movement of heavy solid masses. In July and August 1872 they obtained the result 5·56, and later in the year 5·50, the former result being considered the better. In 1878 they again obtained the result 5·56, and, as showing the stability of the apparatus, they state that the time of swing of the balance did not vary from 408 seconds by more than one or two tenths for over a year. The most recent value—that found by Mr. C. V. Boys in 1894 by the employment of quartz fibres—is 5·527.

It is only possible to give a brief summary of Cornu's many important spectroscopic researches. In 1878 and 1879 he contributed papers to the Académie des Sciences and to the Royal Society, dealing with the effect of atmospheric absorption on the ultra-violet end of the spectrum. He showed that, from this

cause, it was impossible to obtain the solar spectrum beyond a definite limit, which he fixed at λ 2930. He also gave a formula for the limit as dependent on the altitude of the Sun and the elevation of the observer above sea-level, and proved that the absorption was caused by the oxygen and nitrogen of the atmosphere and not by the aqueous vapour or dust. He confirmed his formula experimentally by showing that a triple line of aluminium at λ 1860 was extinguished by four metres of air.

About the year 1886 Cornu made a series of observations and measures of wave-length of the atmospheric and solar lines which occur in the bands called a, B and A by Ångström and near D. His method of discriminating between solar and telluric lines consisted in throwing on the slit of his spectroscope an image of the two limbs of the Sun in rapid succession. The solar lines are thus displaced alternately to the violet and red, owing to the Sun's rotation, while the atmospheric lines remain stationary.

In 1886, the year after Balmer gave his well-known formula for the wave-lengths of the hydrogen lines, Cornu made careful determinations of their wave-lengths, the ultra-violet hydrogen lines up to that time being only known in the stellar spectra of Huggins and Vogel. In 1885 he concluded, from observations of the spectra of aluminium and thallium, that in metallic spectra there are series of lines which obey a law like that of the hydrogen lines, and that the lines which thus fall into series are the lines which most readily admit of reversal. The later work of Kayser and Runge in the determination of series is well known.

Cornu published maps of the ultra-violet part of the solar spectrum in continuation of Ångström's work. These are extremely accurate, but are not accompanied by tables, and at the present time Rowland's tables are more generally useful. He also investigated the ultra-violet part of many metallic spectra.

When *Nova Cygni* was discovered in 1876 Cornu was the first to investigate its spectrum. As he used a somewhat high dispersion he obtained the emission spectrum only. He measured the wave-lengths of eight bright lines, six of which he identified as C, D_3, *b*, F, $H\gamma$, and the corona line.

On the occasion of the transit of *Venus* in 1874 and later, at the request of the Council of the Observatory of Paris, he considered in what way object glasses made for visual observation could be used photographically. Reverting to an idea of Sir John Herschel's, he showed that the separation of the lenses by a distance rarely more than 1½ per cent. of the focal distance transformed an achromatism adapted for visual rays to one adapted for the photographic rays. He applied his method to obtain photographs of the Moon with the large object glass of the Paris Observatory, and obtained excellent results. It is of interest to note that he profited by the transparency of the

collodion film to guide on a point on the surface of the Moon, and by guiding on it to allow for the motion of the Moon.

When the photographic chart of the sky was begun Cornu was one of the delegates appointed by the Académie des Sciences, and he was an active member of the various astrographic congresses.

The memoirs which Cornu contributed to the Académie des Sciences are models of clear exposition. His lectures and addresses were equally marked for their lucidity and admirable style. In England he lectured on several occasions at the Royal Institution, and in 1899 he gave the Rede lecture at Cambridge on the wave theory of light.

The importance of his scientific work was appreciated both in France and in foreign countries. In 1878 he received the Lacaze prize of the Académie des Sciences and the Rumford Medal of the Royal Society. In 1896 he was President of the Académie des Sciences. In 1886 he was appointed to the Bureau des Longitudes. In England he was elected a foreign member of the Royal Society in 1884; the degree of Hon. Sc. D. was conferred on him at Cambridge in 1899. He was elected an Associate of the Royal Astronomical Society in 1890.

M. Cornu continued to discharge his duties at the École Polytechnique, and was engaged in his usual scientific work till Easter. He left Paris soon afterwards, apparently in the best of health, to spend a short vacation at Orleans. He died on the 12th of April, after a very short illness.

M. Cornu had many friends in England as well as in France, who will feel that his death is a personal no less than a scientific loss.

Hervé Faye was born on the 1st of October 1814. He entered the École Polytechnique in 1832, and in 1836 became an assistant at the Paris Observatory. In 1844 he received the Lalande Prize of the Academy for his discovery of a comet and his subsequent researches on it. In 1847 he became a Member of the Institute, and was shortly afterwards appointed lecturer on Geodesy at the École Polytechnique. In 1854 he became Rector of the Academy and Professor of Astronomy at Nancy. In 1862 he succeeded Biot at the Bureau des Longitudes. In 1870 he was chosen as Inspector-General of Secondary Scientific Education, and in 1874 returned to the École Polytechnique as Professor of Astronomy and Geodesy. He was for a time Minister of Public Instruction.

From 1878–1888 he was Inspector-General of Higher Education.

Faye's discovery of the comet which bears his name was made on the 22nd of November 1843, and communicated to the Academy of Sciences. It was followed on the 6th of December by a communication of the elements of the parabolic orbit obtained from observations made on the 24th and 29th of

ber and the 2nd of December. He soon found that the was moving in an elliptic orbit, and proceeded to calculate the methods given by Gauss in the *Theoria Motus*. He ıticipated in this by Goldschmidt, but it is of interest to e that this was the first comet for which an elliptic orbit ɔmputed from observations extending over a comparatively period. From observations extending over 48 days Faye a period of 7·2 years and an eccentricity of about one-half. is interest in comets led him to compute an elliptic orbit 'Arrest's Comet in 1844, and for De Vico's Comet, which also discovered independently, in the following year. Of ɔ2 papers which appear under his name in the Royal y *Catalogue* as being written between 1843 and 1883 a lerable number relate to comets, especially to the forms of ils and to the evidence which can be deduced as to the nce of a resisting medium. In the former connection he d Donati's Comet and in the latter that of Encke. He ered that the phenomena of comets' tails were to be ıted for by a repulsive force due to the Sun's heat.

number of Faye's earlier memoirs relate to the details of ian observations, such as the division errors of the Circle mbey and the discordances found between direct observa- of zenith distance and those made by reflexion from mercury. s several papers on absolute declinations and the systematic of the earlier catalogues of last century.

ıye was attracted by the problems of solar physics. It t be said that he made observations like those of Carring- r the spectroscopic discoveries which have enriched this f astronomical research during the last half-century, but it ɔ him we owe the first exposition of a theory of the Sun's tution which is in its general outlines accepted at the ıt time.

erschel's theory of the Sun as a cool, dark, habitable globe ;enerally held till the middle of last century, and Miss e in her *History of Astronomy* gives a reference to a se upholding this view as late as 1866. Faye, in January communicated to the Academy of Sciences a memoir in he advanced the view that the Sun is to be regarded as a ɔngine, designed to radiate heat from its surface. "Le est la masse même de l'astre, dotée, dès l'origine, d'une pro- ıse quantité de calorique que la contraction progressive de sse entière contribue à alimenter. La source de froid est ce céleste. Le condensateur, c'est la photosphère. Le n de régularisation, c'est l'invariabilité naturelle de la tem- ure à laquelle se produisent les combinaisons chimiques, et lle où elles se détruisent. Le jeu de la machine consiste ɔurants ascendants et descendants, les uns charriant des ars, les autres des substances solides et refroidies. Le en de transport de la chaleur, du centre à la superficie, iste en ce que ces substances solides ou oxydées emprun-

tent aux couches centrales, pour se dissocier, une quantité que leurs vapeurs reportent plus haut, dans la photosphère, ou reproduisent en se combinant." *

Faye is perhaps best known for his daring attempt to supersede Laplace's explanation of the formation of the planetary system. His views are expounded in the *Comptes Rendus*, vol. xc., in the *Annuaire pour l'An* 1885, *Bureau des Longitudes*, and in his essay *Sur l'Origine du Monde*. An account of Faye's theory and a critical estimate of its value is given by Professor G. H. Darwin in *Nature* for the 2nd of April 1885. Faye contended that if Laplace's nebular hypothesis were correct the satellites, not only of *Uranus* and *Neptune*, but of all the planets would have a retrograde motion. He met this difficulty by assuming evolution from meteorites rather than nebulous matter, and by the aggregation of the inner planets in the midst of these meteorites before their masses were mainly condensed in a central Sun.

"On the whole," Professor Darwin concludes, "we must hold the opinion that there are great difficulties in the acceptance of M. Faye's theory, notwithstanding its excellences. The time does not appear yet ripe for definite judgment on this very complex subject, but science is undoubtedly the gainer by such suggestive theories. Whilst a false statement of fact always proves a serious detriment, the enunciation of false or partially true theories is always the incentive to, or initiation of, the discovery of truth."

In addition to many Academic distinctions Faye received the Grand Cross of the Legion of Honour, in recognition of his numerous services to the Government. His scientific labours were acknowledged and appreciated by learned societies in Europe and America, who enrolled him among their members. He has been an Associate of our Society since 1848, and it is of interest to note that he was elected on the same day as Professor Galle of Berlin and Dr. Otto Struve. These names carry us back a long way in the history of Astronomy, our next oldest Associates being Dr. Arthur Auwers and Dr. Wilhelm Förster, who were elected in 1866, eighteen years later.

M. Faye died on the 4th of July, at the age of 87, his death being followed a few months later by that of Madame Faye.

* *L'Origine du Monde*, p. 237.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

Transit Circle.—During the year 1902 10,232 observations of transits and 8624 of zenith distances have been obtained. The progress made in the observations of the 10,000 stars within 26° of the pole, which will be used as reference stars for the astrographic photographs, is satisfactory, about 30,000 observations, or 60 per cent. of the total number required, having been made. The most troublesome observations, those of the 1400 stars within 10° of the pole, have all been made, with the exception of about 50. The observation of fundamental stars was also carried on continuously, a minimum of three determinations of right ascension and two of declination being obtained during the year for each star in the Greenwich clock star list. The Sun has been observed 159 times with the transit circle, its horizontal diameter 119 times, and its vertical diameter 145 times. The Moon has been observed 97 times in R.A. and N.P.D.; the mean error in R.A. of Hansen's Lunar Tables with Newcomb's corrections is $-0^s.161$. The errors since 1883, when Newcomb's corrections were introduced into the *Nautical Almanac*, are as follows:—1883-1893, $+0^s.043$; 1894-1896, $-0^s.057$; 1897-1901, $-0^s.137$; 1902, $-0^s.161$.

The R − D discordance agrees with the values found in the last three years, the correction to the D observation being—

$+0''.08 + 0''.22$ sin Z.D. in 1899,
$+0''.09 + 0''.32$ sin Z.D. in 1900,
$+0''.06 + 0''.44$ sin Z.D. in 1901.
$+0''.05 + 0''.26$ sin Z.D. in 1902.

The re-reduction of Groombridge's observations has been pushed on energetically. The daily results are all finished, so as to exhibit mean R.A. and N.P.D. for the year of observation. The precessions are not yet computed, nor the reduction to 1810·0,

but these are in progress, and at the same time examination of all discordant results is being made.

The Altazimuth.—This instrument has been used as a reversible transit instrument in all four positions. During the year 1458 observations of right ascension and 1127 of north polar distance of the Sun, Moon, planets, and stars have been made. The nadir has been observed 411 times; 99 reflexion and direct observations of stars have been made, and 10 determinations of flexure on the collimators. The Moon has been observed 31 times on the meridian. Out of the meridian 240 azimuths and zenith distances of stars, 31 of the Moon, and 3 of *Venus* have been obtained. The observations for 1899 and 1900 are printed and will appear in the Greenwich volume for 1900.

The Reflex Zenith Tube.—Observations with this instrument, which were discontinued for a few years, have been resumed, as Mr. Chandler has shown (*Astron. Journ.* No. 511) that the anomalous results previously obtained are explained by the variation of latitude. By modifying the illumination somewhat it has been found that stars down to $6^{m}\cdot5$ can be observed, and by mounting the eyepiece on a slide good definition at a distance of nearly 1° from the zenith (centre of the field) has been secured. Additional wires have been inserted, in order that observations may be extended to stars as far as this distance from the zenith. Since May 27, when this was done, 111 double observations and 21 single observations of stars have been made. The stars observed most frequently are:

	Number of Double Obs.		Number of Double Obs.
β Drac.	9	π′ Cygni	9
30 „	6	β Lacertæ	13
γ „	22	9 „	15
12 Cygni	5	Gr. 3087	5

Observations have also been made to determine the intervals of the wires and the mean value and errors of the screw.

Equatorials.—Occultations of 17 stars by the Moon have been observed by one or more observers during the year. The results are printed in *Monthly Notices*, vol. lxiii. 3.

28-inch Refractor.—The weather throughout the year has been unfavourable for double-star observations, but the programme of constantly observing all close and rapid binaries and of the difficult stars for which a large telescope is required has been carried out as far as possible. The stars measured during the year are:

106 pairs under $0''\cdot5$ apart,
86 „ between $0''\cdot5$ and $1''\cdot0$,
89 „ „ $1''\cdot0$ and $2''\cdot0$,
and 78 „ more than $2''\cdot0$ apart

On the average the stars whose distance apart is less than 1″·0 were measured on 2½ nights, and those whose distance apart is greater than 1″·0 on 2 nights.

The following list gives some of the most interesting stars measured during the year :

Star.	Mags		Dist.	Star.	Mags.		Dist.
	m	m	″		m	m	″
ε Hydræ	3·5	6·0	0·1	42 Comæ	5·5	5·9	0·4
β 1266	7·2	7·5	0·2	γ^2 Androm.	5·0	6·2	0·4
β 524	6·0	7·0	0·2	β 733	6·0	11·0	0·7
β 525	7·0	7·0	0·2	β 603	6·4	10·2	0·8
Σ 2367	7·0	7·5	0·2	β 1081	4·5	14·0	5·2
ζ Bootis	3·5	3·9	0·2	β 1082	6·0	9·6	1·2
β 612	6·4	6·5	0·2	Procyon	1	14	5·3
β 614	6·0	9·5	1·0				

In addition good series of observations have been obtained of—

Star.	Mags.		Dist.	Star.	Mags.		Dist.
	m	m	″		m	m	″
κ Pegasi	3·9	5·0	0·1	ζ Herculis	3·0	6·5	1·1
δ Equulei	4·5	5·0	0·1	70 Ophiuchi	4·1	6·1	1·6

A few observations of *Capella* have also been obtained.

Thompson Equatorial.—With the 26-inch refractor 61 photographs of *Neptune* and its satellite were obtained, of which 51 were measured. The results were communicated to the Society. At the present opposition 15 photographs were obtained before the end of December. Eighteen photographs of *Eros* were taken, either with the 30-inch reflector or 26-inch refractor, but only 5 of these are sufficiently good to measure. Comet *b* 1902 was photographed 4 times with the 26-inch. of which only one was measured, and 43 times with the reflector, of which 28 were measured. With an hour's exposure a very satisfactory photograph of the comet was obtained, showing the character of the tail. This was reproduced in *Monthly Notices*. Three successful photographs of Comet *d* 1902 were also obtained.

With the spectroscope 43 photographs of the spectra of some of the brighter stars have been obtained.

Astrographic Equatorial.—During the year 237 plates have been taken on 62 nights. Of these 25 taken for the Astrographic Chart or Catalogue have been rejected—viz. 14 because the exposure was interrupted by cloud or the plate did not come up to the standard in showing faint stars, 5 owing to errors of setting or guiding, and 6 for other defects. Of the remaining 212 plates 64 were of Nova *Persei*, 4 of the field surrounding

Eros, on which, however, the planet was not shown, 73 for th Astrographic Chart, 48 for the catalogue, 12 for the adjustment of the instrument, and 11 of Comet *b* 1902, of which, howeve only one showed the comet sufficiently distinctly for good measure to be made.

Fourteen photographs of the pole have been taken with th Abney and Dallmeyer lenses of 33 inches focus, which cover field of radius $4\frac{1}{3}°$. These photographs are taken with a view t obtain more accurate positions of the close polar stars used i determining azimuth error with meridian instruments.

During the year 1902 98 plates were measured, both in th direct and reversed positions of the plate, by two measurer who measured the 6^m and 3^m images respectively. The part c the sky measured during the year comprises zone +76° fro R.A. 20^h to R.A. 0^h, zone +77°, zone +78° (omitting abou one hour), and zone 79° from R.A. 0^h to R.A. 1^h, the number c stars measured in this area being about 18,300. There has bee a steady and remarkable increase in the number of stars pe square degree in the different zones, as the following tabl shows :

Zone.	No. of Stars Measured.	Area in Square Degrees.	No. of Stars per Sq. Degree.	Zone.	No. of Stars Measured.	Area in Square Degrees.	No. of Stars per Sq. Degree.
64°	8,954	155	58	72°	10,080	108	93
65°	9,239	149	62	73°	9,120	102	89
66°	9,505	143	67	74°	8,720	96	91
67°	9,586	138	70	75°	9,310	90	103
68°	9,939	132	75	76°	8,800	84	105
69°	10,745	126	85	77°	8,500	78	109
70°	10,954	120	91	78°	8,100	72	113
71°	10,939	114	96	...	...	...	...

Altogether 898 plates out of 1149 have been measured, covering an area of 1710 square degrees out of 2088; thus 80 per cent. of the measurement is completed.

The measures of zone 71° have been printed during the year, thus completing the first half of the Greenwich zone. These measures, covering the part of the sky from Decl. 64° to 72°, form a volume of 732 pages.

During the year 51 chart plates have been counted; the area between Decl. 65° and Decl. 70° is completed, and a paper on the statistics of the stars in this part of the sky was communicated to the Society last month. Zone 64° has been counted from R.A. 0^h to R.A. $1^h\ 40^m$.

Plate constants have been computed for the 132 plates whose centres are at Decl. 70° and Decl. 71°, and those for the plates

whose centres are at Decl. 72° are in progress. The standard co-ordinates of the reference stars were computed from a provisional catalogue derived from the Greenwich observations from 1897–1901, with very satisfactory results, showing that a very high accuracy will be reached when the observations of the reference stars by the transit-circle are completed.

As explained in a short note communicated to the Society last month it is proposed to reproduce the chart plates by purely photographic processes on double the scale. Fifty copies of each plate will be made and distributed among the 18 observatories contributing to the Astrographic Chart and to other important observatories and scientific institutions.

Photoheliograph.—Photographs of the Sun have been taken on 182 days with the Thompson photoheliograph of 9 inches aperture. Of the photographs taken 386 have been selected for preservation, including 21 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1902 September 15, and from Mauritius up to 1902 June 20, the year ending on the latter date being represented on 357 days out of the 365 by a photograph from one or other of the three observatories.

The photographs taken at Greenwich have been measured in duplicate up to the end of 1902, and the measures reduced. The photographs from India and Mauritius have also been measured and reduced so far as received, and the copy for press written. The completion of the spot-ledger for the year, and the computation of the annual means, are waiting the receipt of photographs required to fill up gaps in the series since 1902 June 20.

The solar activity in 1902 has been very small, but has unmistakably increased since the previous year. The spotted area is distinctly larger than in 1901, and on 1902 September 17 a period of sustained activity set in. The faculæ too have shown a striking development since 1901; so that there can be no doubt that the period of minimum has been passed, and that the new cycle has been definitely entered upon.

Longitude of Paris.—Operations for the re-determination of the difference of longitude between Greenwich and Paris were carried out in the spring and autumn, observations being made simultaneously by two French and two English observers at adjacent stations. The observations, both in the spring and autumn, were made in three groups of three, six, and three full nights (or their equivalents in half-nights), the observers with their instruments being interchanged between the first and second and again between the second and third parts. The French observers were M. Bigourdan and M. Lancelin (M. Lancelin replaced M. Rénan, who was taken seriously ill soon after the commencement), and the English Mr. Dyson and

Mr. Hollis. The following table gives a summary of the number of nights of observation of the English observers:

	Date.	Observer at Paris.	Observer at Greenwich.	No. of Nights on which Signals were Exchanged.	No. of Fine Nights. Paris.	Greenwich.	Simultaneous P. & G.
I.	March 17–30 ...	D.	H.	13	5	9	4
II.	April 6–24 ...	H.	D.	19	9	11	6
III.	April 27–May 3	D.	H.	7	3	5	3
I.	Sept. 21–26 ...	H.	D.	6	4	5	3
II.	Sept. 29–Oct. 22	D.	H.	24	11	13	8
III.	Oct. 25–Nov. 4	H.	D.	11	8	6	5

The reduction of the observations is in progress.

The printing of the volume of *Greenwich Observations for* 1900 is completed with the exception of the introduction. The volume for 1901 is printed as far as the transit-circle ledgers. Copy for press of the transits and zenith distances observed with the altazimuth has been sent to the printers. The heliographic results are printed. The measures of the astrographic plates have been printed from Decl. 64° to Decl. 72° (about one-half of the part undertaken). The introduction to the volume, which will contain these measures, is nearly completed.

The rearrangement of the books and the new card catalogue of the general astronomical library have added considerably to its utility.

Royal Observatory, Cape of Good Hope.

In the last report reasons were given for the adoption of a new departure in the method of mounting the meridian marks of the new Transit Circle—by which the actual lines of azimuthal reference will be made to depend on marks attached to the bed-rock at considerable distances below the surface of the ground. The pits giving access to these marks must necessarily be water-tight. The original plan was to line the pits with cast iron; but, by order of the Admiralty Director of Works, an attempt was made in the first place to exclude water by brick and cement. This plan was tried for two pits but completely failed, and after considerable delay the plan of lining all the shafts with cast-iron cylinders was sanctioned. The lowest of these flanged cylinders, with thick cast-iron bottoms, have now been received, and the other open cylinders are being delivered from the Cape Town foundry at the rate of two per week, so that it is hoped this work will shortly be completed. It will then be possible to begin erection of the piers and houses for the collimators and marks, and to bring the instrument into regular use.

The investigations of the errors of all the micrometer screws have been completed, and a very thorough and satisfactory determination of the errors of the pivots has been made. The

pivots are of flint hard steel and their errors are quite considerable, but as the errors run very smoothly, and are completely determined with perfect agreement in the two positions of the axis, and are little liable to change, this is a matter of no consequence, as their effects will be completely eliminated in the reduced results.

The spectroscope of the Victoria Telescope has been, since November 1901, in the hands of the Cambridge Instrument Company, for the purpose of adapting four very transparent prisms in lieu of the three original prisms, which, as experience proved, absorbed too much of the rays of higher refrangibility. In addition to this alteration, new and very efficient automatic means have been applied for maintaining a constant temperature of the prisms.

The new Sidereal Clock—or rather, recording pendulum, swinging in a glass cylinder automatically maintained at constant temperature and pressure—is also approaching completion. The construction of this clock has been in the hands of the Cambridge Instrument Company since 1900, and it is now under trial. Mr. Lunt, being in England on leave, has been placed in charge of the tests and experiments connected with the spectroscope and clock, and has given most helpful aid to Mr. Horace Darwin in connection with that work. Zeiss, of Jena, reports that the $11\frac{1}{3}°$ objective prism of 24 inches aperture, presented by Mr. McClean, is ready for mounting; the $8\frac{1}{4}°$ Grubb objective prism and its mountings have been sent to Jena to be remounted in combination with the Zeiss prism.

The Cape Occultations 1881–95 (441 in number), reduced and compared with Hansen's Tables of the Moon, have been printed as Part 3 of Vol. II. of the Cape *Annals*. The Cape Day Numbers for 1904 are printed, and those for 1905 are in the press.

The Catalogue of 8560 stars for the Equinox 1900, to be used as standard stars for the Cape Astrographic Zone—Declination $-40°$ to $-52°$ is in press.

Parts I., II., and III. of Vol. IX. of the *Annals of the Cape Observatory* have been passed through press by Mr. Innes during his leave in England. The volume will contain the results of a revision of the *Cape Photographic Durchmusterung*, viz.:

Part I.—Results of examination of questions which have arisen from a comparison of other star-catalogues with the C. P. D.

Part II.—List of stars suspected by Prof. J. C. Kapteyn of variability, with the results of revision. Observations of variable stars. Miscellaneous stars examined. Observations of stars marked ? and *x* in the C. P. D. List of coloured stars observed in the course of the revision. Statistics of stars in the southern hemisphere to 9·0 magnitude inclusive.

Part III.—Errata in existing Southern Star Catalogues (for stars south of declination $-19°$).

Part IV. will consist of investigations on the proper motions of stars (chiefly stars suspected by Kapteyn of considerable

proper motion), but the work is delayed by non-completion of the necessary observations.

Vol. X., Part I. of the *Annals* containing Mr. Lunt's investigations on the spectra of silicon and oxygen has been passed through press by him in England.

The discussion of the heliometer triangulation of the southern circumpolar area, referred to in previous reports, has now been completed by Mr. Hough, and the manuscript has been forwarded to the printer. This discussion forms Part I. of Vol. XI. of the Cape *Annals*—a volume that will be dedicated to a discussion of all existing material bearing on the positions of the southern circumpolar stars. Part II. of the same volume will contain the discussion of a series of photographic plates covering the same area, the reductions involved in which are now well advanced.

The general work of the transit circle has been confined to observation of stars of the new working list (see Report, February 1900). The observations made have been :

Number of transits		7380
Determinations of Z.D.		6807
,,	collimation	95
,,	level	307
,,	azimuth	326
,,	run	291
,,	nadir	290
,,	flexure	23

The reductions of the meridian observations to apparent place are complete to the end of 1902, and to mean place till June 1902. Mr. Power has given considerable time to the investigation of questions raised by Dr. Ristenpart in connection with possible errata in the Cape Catalogues for 1840 and 1850. This work has been hampered by the fact that these MSS. were unarranged and in some part incomplete. The whole of these old MSS. are now being collected and bound.

Observations of 43 separate phenomena of occultations of stars by the Moon were obtained as follows :

	D.D.	R.D.
Phenomena predicted by the Nautical Almanac Office	15	10
Other occultations	18	
Total	33	10

Of these phenomena 7 were observed by 2 observers.

Comet Perrine has been observed on four mornings with the heliometer. The first observation was obtained on December 22 ;

the object is still under observation. A run of unfavourable weather prevented earlier observations.

With the 24-inch objective and Grubb object-glass prism of the Victoria telescope 280 successful star spectra (3·5 to 5·5 mag.) have been taken.

Experimental trials of enlarging lenses have been made, none of which have led to satisfactory results, but a number of very successful photographs of interesting objects have been secured in the primary focus of the telescope.

With the 18-inch visual objective of the Victoria telescope Mr. Innes has made 384 complete sets of measures (distance and position-angle) of 239 pairs of double stars.

In the course of the year 27 stars have been noted which were not previously catalogued as double, viz. :

11 pairs with the 18-inch,
8 „ „ 7-inch,
8 „ at the transit circle.

These new pairs have all been measured micrometrically.

During the year Mr. Innes has proved the variability of the two following stars :—

Name.	R.A. 1875. h m s	Dec. 1875. ° ′	Range of Mag.	Period.
C.DM. −42°,845	2 26 27	−42 0·8	10·0 to 11·5	260 days
C.Z. 3ʰ No. 721	3 24 22	−28 50·0	8·5 to 9·75	95 „ ?

The star *G. P. Z.* 7641, mag. 8·7, is found to belong to the category of stars having a regular nebulous envelope.

Very elaborate investigations of the spectra of silicon and oxygen have been completed, as well as investigations on the spectra of *ε Canis Majoris*, *β Crucis*, *Sirius* and *Canopus*, and on various sources of systematic error in line-of-sight work.

The following oppositions of major planets have been observed with the heliometer during the year :

	No. of Obs.	
Opposition of Uranus	54	
„ Saturn	33	
„ Jupiter	31	
„ Neptune	62 in two oppositions.*	Early and late in 1902.

A new determination of the parallax of *α Centauri* has been undertaken by Messrs. Cookson and Lowinger, in connection with which 476 observations have been made in course of the year. Mr. Cookson has also continued his observations of the relative position-angles and distances of *Jupiter's* satellites. Of these

* See also Report for 1901.

he has obtained 570 observations on forty-eight nights in 1902. He has also completed the reduction and discussion of the whole of the observations of a similar series made in 1901; the reduction of the observations of 1902 is finished, together with the comparison of the observations with the corresponding tabular quantities; most of the coefficients of the unknown quantities are also computed.

With the Astrographic telescope the following work has been accomplished:

	No. of Plates.	No. of Exposures.	Duration of each Exposure.
			m m m
Triple exposure chart plates passed ...	103	309	30, 30, 30
,, ,, ,, rejected...	19	57	30, 30, 30
			m m s
Revision Catalogue plates passed ...	337	1011	6, 3, 20
,, ,, ,, rejected ...	114	342	6, 3, 20
Jupiter's satellites	48	556	5s + trail
Adjustment plates—focus, orientation, &c.	14	...	various
			m
Galactic areas	7	14	10
Search for Ultra Neptunian planet ...	8	16	45

The plates of *Jupiter's* satellites have been taken for the same purpose as the heliometer measures.

The aperture of the object-glass was reduced by a diaphragm to six inches diameter. Every plate contains six exposures of the satellites each of five seconds, and six exposures of the standard stars of the same. The image of *Jupiter* was also allowed to trail across the plate; the satellites, except such of them as happened to be close to the planet, also recording their trails. It is hoped that these trails will furnish a valuable control on the inclinations of the orbits. The work of measuring the catalogue plates has been very seriously hindered by the resignation, early in the year, of five out of the six ladies previously employed on measurement, a result due mainly to the high rates of pay given in Johannesburg. The training of a new staff has cost much time. In consequence, only thirty-seven plates, containing 28,683 stars, have been measured during the year, as compared with 159 plates containing 100,203 stars, measured in 1901.

The total number of plates measured is now 434, containing 248,921 stars. The coordinates of every star have been measured in two opposite positions of the plate, and all the standard stars have been so measured by each of two observers. When either coordinate of any star differs by $0''{\cdot}6$ from the corresponding coordinate resulting from the measure in the reversed position of the plate, the observations in both positions of the plate are repeated.

Some progress has been made with the formation of a catalogue of the standard stars of the astrographic zone, based on

the two series of astrographic plates, so as to determine the approximate proper motions of such stars as have not been previously observed on the meridian. The necessary reduction-tables have been prepared, and the tabular rectangular coordinates have been computed for all the plates whose centres are $-41°$ and $-42°$.

The computation of the field work of the geodetic triangulation, so far as it has been carried out in Rhodesia, is nearly completed.

Field work there will be recommenced before the middle of 1903, on the arc along the 30th meridian between the Zambesi and Lake Tanganyika.

Field operations on the Anglo-German boundary between British Bechuanaland and German S.W. Africa were suspended in May, it being absolutely necessary to give the observers rest and change of climate. The northern part of the work proved peculiarly trying and difficult, and only possible of execution during certain months of the year. Major Laffan, R.E., the English Commissioner, has now returned to duty: he sailed from Simon's Bay for Swakopmund in H.M.S. "Pearl" on December 12, to meet his German colleague who went there direct from Germany.

Some idea of the difficulties encountered in the work may be formed from the fact that several of the stations are forty miles from the nearest known spring of water, and even that very unreliable in quantity.

The field work of the main triangulation is now finished. The angles have been reduced, the figures discussed, and the definitive geodetic latitudes and longitudes computed at the Observatory and supplied to the Commissioners. Some of the astronomical observations remain to be computed. The boundary from South Reitfontein to the Orange River has been beaconed, and if the season is favourable the remainder of the boundary will probably be demarcated during the next few months.

Mr. Heatlie, formerly engaged on the geodetic survey of Rhodesia, has been employed to assist Major Laffan in order to press on the work, and, if possible, to complete it during the short season that water melons are available, as the juice of this fruit is the only source of water supply in some of the arid districts traversed by the boundary.

The volume containing the re-reduction of Bailey's and Maclear's Survey has been distributed.

H.M. Astronomer, during a visit to Lord Milner at Johannesburg in July last, submitted plans for an Ordnance Survey of the Transvaal and Orange River Colony. These plans have been adopted, and Colonel Morris, R.E., C.B., has been appointed in charge of the work which is now being organised. The preliminary arrangements have thrown a large amount of work on H.M. Astronomer.

The records of the seismograph have been regularly forwarded

to Professor Milne, secretary to the Seismological Committee of the British Association.

The meteorological observations made during 1902 have been communicated to the Cape Meteorological Commission.

Mr. Hough, chief assistant, who was absent on leave in England from September 11, 1901, returned to duty on February 4, 1902.

Mr. Lunt has been on leave of absence in England (and subsequently on duty at Cambridge, as already mentioned) since May 7.

Mr. Innes has been on leave of absence in England since August 19.

Mr. Power has performed the secretarial duties of the Observatory in the absence of Mr. Innes.

Royal Observatory, Edinburgh.

The time service for the cities of Edinburgh and Dundee has been carried on as in former years, the various clocks concerned being under electric control from the Molyneux mean-time clock of this observatory. On six days in the course of the year the one o'clock gun was not fired, some part or other of the apparatus being under repair. One bad signal was made, the gun being fired one second too late on August 19th, owing to an accidental entanglement of the line wire. The time-ball was not raised on September 3 on account of the violence of the gale on that day.

Dr. Halm has continued his spectroscopic observations of the rotation of the Sun with the spectro-heliometer devised by him for the purpose, and the results so far, besides confirming Prof. Duner's well-known conclusions, seem already to indicate systematic changes in the angular momentum of the photospheric layers, probably connected with the Sun's activity. The method adopted by Dr. Halm appears to be of sufficient accuracy for detecting small variations of the Sun's rotational velocity, and it is hoped that the observations can be continued for several years in succession in order to test the character of the law of rotation at different phases of the sun-spot cycle. The 15-inch refractor was used by Dr. Halm for observations of comets and minor planets.

The computations of precession and secular variations of all the stars of the Henderson Catalogue have now been completed by Dr. Halm with the assistance of the temporary computer, and the results have been carefully checked. A comparison of the star places with the Fundamental Catalogue of the Astronomische Gesellschaft has been made by Professor Auwers, and at the same time independently by Dr. Halm, who has also compared the declinations with Professor Boss' Catalogue. It appears from these investigations that the transit observations of

the earlier period, 1835–40, are in better agreement with the Fundamental Catalogue than those made during 1840–45, and that the cause of the later discrepancies may perhaps be due to wear in the pivots. The declinations are in very close accordance with Boss' standard declinations. The discrepancies between the right ascensions and the declinations of stars observed in different years are on the whole larger than might have been expected. There can, however, be no doubt that this is partly due to outstanding errors in the instruments, especially to rapid temperature changes of the azimuth and level of the transit instrument, and accidental division errors of the mural circle. Dr. Halm is now engaged on a general revision of the work and comparison of the star places with other catalogues.

The transit circle has been under Mr. Clark's charge, the programme for the year including Sir David Gill's list of zodiacal stars and Cape heliometer comparison stars, besides the usual clock star list. The observations made during the year include 308 of clock stars, 614 of stars from the zodiacal list, 85 of heliometer comparison stars, besides 126 observations of stars for azimuth. The list of seventeen heliometer comparison stars for the 1903 opposition of *Jupiter* has been completed, each star having been observed five times, in accordance with Sir D. Gill's recommendation. Mr. Clark also observed the place of Nova *Persei* six times, and that of Comet *b*, 1902, three times with bright wire illumination. Determinations of the instrumental errors were made as frequently as possible, the collimation being measured thirty-three, level fifty-seven, and nadir sixty-seven times. Two special determinations were also made of runs and one of flexure. The results of these measures have shown the same marked constancy in the position of the instrument as was found in former years. The definitive reductions of the observations made with the transit circle at Blackford Hill have been taken in hand, and are making rapid progress. The observations of Nova *Persei* and of Comet *b* made during the past year are ready for publication.

The Milne Seismograph has now been in operation for over two years, and the resulting records of unfelt tremors have been as satisfactory during the past year as in the preceding. Traces of fifty-two earthquakes which occurred during 1902, varying in amplitude from 0·25 mm. to 22·0 mm., have been found on the photographic rolls. In duration they have varied from a few minutes in the case of disturbances of small amplitude to between three and four hours for the more pronounced movements. The most remarkable records are those of the earthquakes in Guatemala on April 19 and September 23, and of that in Kashgar on August 22.

The usual meteorological observations have been carried on by the staff of the Observatory as formerly, and copies of the readings have been supplied to the Registrar-General for Scotland and to the Scottish Meteorological Society. The

Robinson anemometer curves have been regularly tabulated by Mr. Clark.

A watch for the Leonid meteors was kept during the whole night of November 15 by the staff of the Observatory, but without success. This was the only fairly clear night near the epoch of the meteors.

The 24-inch Grubb reflecting equatorial has been used by Mr. Heath for photographing nebulæ.

Cambridge Observatory.

Meridian Circle.—Owing to unfavourable weather and unavoidable delays the meridian circle was used for observations during the year 1902 on only twenty-six nights.

From the beginning of the year to the middle of June the work was chiefly confined to the observation and reduction of Sir David Gill's Catalogue of 2798 zodiacal stars : 1690 complete observations were made in the right ascension and declination of these stars, including 392 observations of clock stars.

On 1902 June 17 the observation of Sir David Gill's second list of heliometer comparison stars was begun, and 572 complete observations were made, including 112 of clock stars. The work was delayed by the collapse of one of the spider lines in the eye end. On August 11 it was found that G, one of the supplementa wires used in observing circumpolars, had broken, curled up, an fallen on its neighbour, wire V, one of the seven used in observin quick stars, so that both wires were rendered useless. Th vertical wires were replaced by a fresh set of spider lines at t works of the Cambridge Scientific Instrument Company, a eighteen nights, from August 14 to September 16, were devot chiefly to the observation of circumpolars, to obtain material f the computation of the equatorial intervals of the fresh set wires. Provisional intervals were calculated from fifty-ni observations of close circumpolar stars, and 305 of more dista t made 1902 August 14–October 4, and have been used fr m August 14 to the end of the year : when a fresh determinati on has been made from 109 observations of circumpolars and 41 observations of quick stars.

The observation of the heliometer comparison stars and of the zodiacal stars was resumed on September 17.

The total number of observations made during the year is 2902, comprising 1690 of zodiacal stars, 572 of heliometer comparison stars, 353 of clock stars, and 287 of circumpolar stars, including fifty-six of *Polaris* at the upper transit and seventy-five at the lower.

The work of reducing these observations is well advanced. The reductions are completed to mean equinox at the beginning of the year to 1902 June 18, and to apparent right ascension and apparent declination to the end of October.

The results of the observations made for the catalogue of zodiacal stars have been collected and arranged in order of right ascension. They comprise observations of 1785 stars. Of the remaining stars in the catalogue 116 are fundamental stars and eighty-six are too far south to admit of their being observed with the Cambridge meridian circle. There are thus 812 stars in the catalogue remaining to be observed.

The nadir point, level, and line collimation have been regularly observed, and the constants for instrumental correction obtained 229 times, each time chiefly from two equations, sometimes from three—in all 476 equations.

Sheepshanks Photographic Equatorial.—Since the last report to the Society considerable progress has been made with the reduction of *Eros* photographs for a new determination of the solar parallax. In June an account was given of the second part of an experimental reduction of a small number of photographs made nearly simultaneously at Mount Hamilton, Minneapolis, and Cambridge. Two conclusions were drawn from this instalment of the work—(1) that the method of reduction in rectangular coordinates throughout was so far successful as to be worthy of a more extended trial; and (2) that it was very desirable that all the photographs made at different observatories should as far as possible be combined into one solution. A request was therefore made to the directors of some ten observatories that they should measure their *Eros* photographs obtained during the nine days 1900 November 7–15 inclusive, and send the measures to Cambridge, with permission to combine them into one solution for a further trial of the methods used in the preliminary reductions. A very kind and ready response was made to this request, and a good deal of material has already reached Cambridge. We are indebted to the directors of the observatories of Paris, San Fernando, and Algiers for measures of the planet and of the *étoiles de repère* on all their plates taken during those nine days; and results from a number of other observatories are promised, and will be shortly available. We are indebted to M. Lœwy for the publication (circular No. 9) of separate heliocentric ephemerides of the planet to the Earth.

With the aid of a grant from the Government Grant Fund of the Royal Society we have been able to secure the help of two ladies, formerly students of Girton College, as computers. The first step is to form a uniform system of places of the comparative stars by combining measures or overlapping plates. This work is well in hand.

With the telescope a beginning has been made of a series of photographs of selected fields for the determination of stellar parallax.

The Newall Telescope, Cambridge Observatory.

The Newall telescope was used for observations on 61 n in the course of the year 1902, this having been the mos propitious year for observations since the instrument was inst at Cambridge.

The instrument has been used throughout the year in nection with the four-prism spectroscope, which was readjust January, in place of a two-prism spectroscope that had be use most of the previous year. Special attention has devoted to the spectrum of *Sirius*, *Procyon*, and *a Persei* otherwise the work has been confined to stars which occ the short list adopted in the plan of co-operation recentl augurated between some of the observatories engaged in " of-sight" work. The year has been unfavourable for p graphic work; 98 photographs of stellar spectra have obtained; and in addition to these about fifty have rejected on account of insufficient exposure or interruptio clouds. In the laboratory about 200 spectra have been p graphed, partly in the process of testing the adjustments o spectroscope, and partly in the study of the spectru magnesium, specially with a view to the determination o wave length of the blue line at 4481 λ. This line has, much experimenting, been obtained narrow and defined en for exact determination of the wave length.

A gas engine and dynamo have been installed in the annex for use in spectroscopic observations.

Dunsink Observatory.

The observations of Sir David Gill's zodiacal stars are completed. These were commenced in 1900 January, and o 2798 stars on the list about 2100 have received at least observations, while about 300 have been observed less than times. The months of June, July, and August in each year extremely unfavourable for observation, and accordingly few stars between 14^h and 18^h R.A. have been cut out. every probability of similar weather in succeeding years it not seem to be desirable to prolong the work in order to fi this gap. The total number of these observations amount 20,367, and consists of 10,378 in R.A. and 9989 in D arranged as follows:—

R.A.		Decl.	
Zodiacal stars ...	8,932	Zodiacal stars ...	8,9
Standard stars ...	877	Standard stars ...	7
Azimuth stars ...	177	Nadir	1
Collimation... ...	190	Runs	
Level	202		
Total in R.A. ...	10.378	Total in Decl. ...	9.9

The observations have been reduced to apparent place in R.A. to 1902 August 27, and in declination to 1901 October 21.

During the year 1902 the number of observations made with the meridian circle is 7516, consisting of 3346 observations in R.A. of the zodiacal stars, 299 observations of *Berliner Jahrbuch* stars for clock correction, 61 determinations of level and 61 of collimation, while 54 stars were observed for azimuth error. In declination 3346 observations were made of the zodiacal stars, 258 stars were observed for the equator point of the circle, 61 determinations were made of the nadir point and 30 of the error of runs. In order to carry on the reductions observations with the meridian circle were discontinued in the latter part of the year except for determinations of clock error.

The Roberts telescope has been used throughout the year in photographing clusters, and some photographs of the comet 1902 *b* were also obtained.

The South equatorial has principally been used in showing visitors objects of interest on the first Saturday of each month.

The time service to Dublin has been carried on as heretofore, and the time ball on the Port and Dock Office has been let fall daily at 1^h G.M.T.

Durham Observatory.

During the past year 663 transits have been taken with the Almucantar upon forty-four nights. The reduction of these is almost completed, and it is hoped shortly to publish an account of them.

The Almucantar has been provided with a wind screen, which makes it possible to observe with it on many nights when the wind would otherwise have been too high.

A great deal of time has been devoted to the discussion of the Harvard observations of eclipses of *Jupiter's* satellites. The whole of the observations have now been charted and the charts measured.

Duplicate calculations of the equations of condition and other requisite quantities, besides some considerable theoretical discussions have been pushed on and are now well advanced. The work has been much facilitated by a grant from the Government Grant Committee. A portion of the theoretical discussion has already been passed for press.

Meteorological work has been carried on as heretofore.

Glasgow Observatory.

Two faint stars in the immediate vicinity of the pole, and α and λ *Ursæ Minoris* were measured with the transit circle in continuation of the work begun in 1897. Owing to the prevailing

unfavourable weather, two or more observations of the fai stars were obtained only on eighteen nights.

The spectrograph, mounted on the 20-inch Breadalba Reflector, was exclusively used in photographing the spectrum Nova *Persei*. From January to May five plates were secur with exposures varying from six to sixteen hours, the last pla being exposed on seven nights—from April 1 to May 2. Th work was taken up again in autumn, and a plate exposed f twenty-three hours on four nights between October 20 an November 1 shows, though faintly, the same lines as were phot graphed at the beginning of the year. A second plate w exposed for twenty-three hours on November 17, 18, 20, and 21 but owing to the continuous bad weather in December (and al in 1903 January) it has not yet been possible to complete th exposure. The plates of 1901 and 1902 have been measured, th work entailing about 25,000 settings. The points measured hav been identified and the reduction to wave-length is almos completed.

Time observations were taken on 101 nights, and th meteorological work has been carried on as in former years.

Liverpool Observatory, Bidston.

The course of observations which has been pursued in earlier years, one adapted to the requirements of the port and the character of the instruments, has been followed without interruption, but without addition, throughout the year. Very considerable attention has been paid to the testing of chronometers and other apparatus for which the Board grants certificates of test: to the distribution of time signals, and to meteorological inquiries. These latter seem to be particularly welcome to the local medical officers of health, and in connection with a recent suggestion that meteorological observations should be suspended for a period of years it seems not undesirable to call attention to a class of scientific men who would apparently suffer if deprived of certain climatic constants.

In the astronomical department, properly so called, the observation of comets has been systematically pursued, and some attention has been given to the observation of double stars. The comets of Perrine and Giacobini have both been observed, and the observation of double stars has been practically limited to those binary systems for which moderate optical means suffices. Concurrently with these inquiries the series of seismological observations is maintained, and a comparison of the results obtained with those recorded at Hamburg and Strassburg shows that the site is admirably adapted for a seismological station. In two out of the three terms lectures are given at the observatory in connection with University College.

In the course of the year the solicitor of the Dock Board gave notice of an intention on the part of the Board to seek powers from Parliament relieving the Trust from its statutory obligations in the matter of maintaining the Observatory. The Board, however, has not seen fit, at present, to prosecute this aim, and the Observatory remains under the same care and maintenance as heretofore.

Radcliffe Observatory, Oxford.

The work done with the Transit Circle during the year has been confined to filling up gaps in the working list of stars described in the Report of this Observatory communicated to the Society in 1900 February, and 1215 transits and 1084 zenith distances have been observed. The reduction of observations, which was still in arrears at the date of the last report, has been pushed on persistently and is now in a very forward state. All the zenith distances have been completely reduced to the end of the year. The right ascension observations have been completely reduced up to 1902 April 28, and the reduction from that date to the end of the year is well in hand.

The definition of the wires in the Transit Circle collimators has been considerably improved by some small alterations which have had the effect of facilitating the determination of horizontal flexure of the instrument, and reducing the effect of personality upon it.

A further attempt was made to determine the pivot errors of the Transit Circle with the arrangement described in the report of this Observatory for the year 1900. The principal difficulties referred to in that report were got over by the use of a good 6½-inch objective for the collimator, kindly lent for the purpose by Sir Howard Grubb. It was found, however, that the reflected image of the wires was affected by a slight swaying movement, due possibly to movements of the ground. As this movement more than masked the small effects of pivot error which we were in search of, and as there appeared no way of eliminating it, the observations have been discontinued.

The Barclay equatorial telescope has been chiefly used for the observations of Nova *Persei*, and determinations of the brightness of this star have been obtained on January 4 and 28 February 10, March 12 and 29, September 3, 5, and 6, and December 31. The results of these observations as far as March 29 were communicated to the Society in June. Nova *Aurigæ* and Comet *b* 1902 (Perrine) have also been observed with this instrument; and the observations of comet Tempel 2, 1899 IV., have been reduced and published in the *Monthly Notices*, vol. lxii. No. 9.

The erection of the new photo-visual refractor has occupied a great deal of time and required a large amount of attention

during the year. The main castings were delivered in Oxford on February 21, and placed in position on March 16. This mounting of the other heavy parts, the axes, crosshead, and tubes, was completed towards the middle of May, when the scaffolding was taken down and the work on the lifting floor was pushed on and completed. Some difficulties arose in this part of the work, but they were all successfully surmounted and the floor now works most satisfactorily. It can be set at any height to a small fraction of an inch, and can be kept there without any sensible "creep" for an indefinite time. The adjustment of the train of prisms and lenses for enabling the R.A., as well as the declination, circle to be read from the eye end through the declination axis was another part of the work of erection which gave a good deal of trouble, but in the end was very satisfactorily accomplished. Early in November the polar axis of the instrument was brought into very approximate adjustment, using a 7-inch finder, which is mounted on the 24-inch tube, but the 24-inch and 18-inch objectives were not inserted in the tube until November 22.

Meteorological observations and automatic registrations have been maintained as usual, and the observation of underground temperature by means of platinum thermometers has been carried on uninterruptedly.

University Observatory, Oxford.

The work of measurement and reduction of plates for the Astrographic Catalogue is approaching completion. The total number of plates completely reduced on December 31 was 1025 out of 1180, the year's work being represented by 126 plates, many of them rather thickly studded. The remaining 155 being in regions of the sky not rich in stars, it is hoped to finish them during 1903. The measures of the *Eros* plates have accordingly been put aside for the present, but will be resumed as soon as the majority of the remaining plates are finished, if funds can be provided for the purpose.

A good deal of experimental work has been done preparatory to interpreting the measured diameters of the star discs in terms of stellar magnitude. Among other things it has been shown indirectly that the diameter is sensibly affected by the distance from the centre of the plate, for the number of stars photographed varies with this distance to the extent of 50 per cent., corresponding to about a whole magnitude (*Monthly Notices*, vol. lxii. p. 434).

An examination of the differences between the places of stars deduced from our measures and the Cambridge meridian observations made from 12 to 22 years earlier has given some valuable information on an important point, raised by Sir David Gill, concerning the systematic motion of bright stars relatively to

faint. This work is still proceeding, but some results have been published (*Monthly Notices*, vol. lxiii. p. 56).

Mr. F. A. Bellamy, on whom has fallen the heavy work of superintending all the reductions for the Astrographic Catalogue, has nevertheless found time to continue his work on stellar distribution. Some points of interest which arose in the course of it have delayed publication.

Mr. H. C. Plummer, M.A., has continued his investigations on the measurement of star images photographed with different instruments (*Monthly Notices*, vol. lxii. pp. 352, 506; vol. lxiii. pp. 14, 16). The result, as regards the parabolic reflector, is somewhat disappointing, for the hope that a study of the geometrical theory would suggest a method of diminishing systematic error in measurement has so far not been realised, but it is hoped that the large amount of work done may serve its purpose in clearing the ground for others. Two short papers by Mr. Plummer on points of mathematical interest have appeared during the year (*Monthly Notices*, vol. lxii. p. 545; vol. lxiii. p. 90).

The work of reducing the Rousdon Observatory observations of variable stars has proved unexpectedly heavy, though it is now approaching completion.

This report would be incomplete without a reference to the excellence of the work done by Mr. B. Gray and Mr. E. A. Gray in measuring and reducing our astrographic plates. Their work, always careful and good, has improved with experience until it has now reached a very high standard of excellence.

Temple Observatory, Rugby.

The object of this Observatory is to give boys a taste for astronomy, and, judging from the increased attendance during the past year, it is doing its duty. From twenty to thirty boys came nearly every fine evening during the autumn months. The measurement of double-stars has been continued as before.

Stonyhurst College Observatory.

The solar surface was observed on 217 days of the past year, 1902, very evenly distributed throughout the twelve months. Drawings were made on 110 days, and on the remaining 107 days careful searching could find no disturbance. The longest period of solar calm was from June 2 to September 18. From September 23 to November 25 there was an appearance of a gradually increasing activity; but throughout December the surface was perfectly calm.

The deduced mean spotted disc-area for the year was 0·33 (the unit being $\frac{1}{1000}$th of visible disc), which is in favour of

returning activity. In the three years 1900–2 the mean areas were respectively 0·55, 0·29, 0·33.

The magnetic variations have been, on the whole, small, and afford no indication of the end of the minimum period. The mean daily range of the declination magnet was closely the same as for the preceding year, being 9′·0, against 9′·1 for 1901. The greatest disturbances occurred on January 15, April 10, and August 21, with extreme oscillations of 32′, 35′, and 36′ respectively. These are compared with the solar surface in the following table :—

Date. Range.	Dates. Spotted Disc-areas.		
Jan. 15 32′	Jan. 9, 13, 14 4·0 1·0 0·6		Jan. 25 to Feb. 12 0
Apr. 10 35′	Mar. 3 to Apr. 9 0	Apr. 10 0·1	Apr. 11 to May 23 0
Aug. 21 36′	July 29 to Aug. 23 0	Aug. 24 0·2	Aug. 25 to Sept. 18 0

The stellar spectrographic work has made but slow progress during the year, owing mostly to the generally cloudy state of the sky after sunset, many of the most promising evenings having failed in this way. About 150 exposures were made, including some purely experimental trials of focus. Of these sixty-six were directed to β *Lyræ*, on the 4-inch prismatic camera, and forty-four plates have been selected for a supplementary paper on the violet end of the star's spectrum. These have been enlarged and mounted, and are ready for a comparative study; but other pressing obligations in the physical laboratory will probably delay this and other reductions until more material has been collected.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

There has been no change in the work of this observatory since the last report. As in previous years it has consisted mainly in the observation of *Jupiter*, the measurement of binary stars, and the usual daily meteorological observations for the Registrar-General, &c.

Wolsingham Observatory (Rev. T. E. Espin's).

The work of measuring double stars has been continued, as in the previous year. The amount of clear sky, especially during the latter part of the year, has been much below the average, and the definition has been generally poor. The results of measures made in the earlier part of the year, together with those in

previous years, were published in *Monthly Notices*, vol. lxii. No. 7. The total number of measures made during the year is 1496. 38 new pairs have been detected.

Sir William Huggins's Observatory, Upper Tulse Hill.

The photography of stellar spectra, which has been in progress for some years, has been continued during the past year.

In the laboratory metallic spectra have been photographed under different experimental conditions in connection with the Observatory work. A preliminary note on the changes of character of the magnesium line at λ 4481 has been published in the *Astrophysical Journal.*

Rousdon Observatory, Lyme Regis, Devon.
(*Late Sir C. Peek's; C. Grover, Observer in Charge.*)

The building has been repainted during the summer, and the instruments are maintained in good working order. The year as a whole has been by no means favourable for astronomical work. The four months April to July, with September and October, were very good for observation, but the remaining six months were very poor. Observations were made on 148 nights, which is somewhat below the average number; but by extended watches on these nights the total amount of work accomplished is nearly up to the average. The 6·4-inch Merz equatorial has been kept at the observations of long-period variable stars; 558 magnitude determinations have been made. Argelander's method has been followed as during the previous sixteen years. At each observation the light of the variable is estimated relatively to five comparison stars in the same field of view, the mean result being assumed to be the magnitude on the date of observation. Thus during the year 1902 about 3000 observations of stellar brightness have been made, and eighteen maxima and seventeen minima have been recorded. About twenty-five long-period variables are under regular observation, and, as most of these are circumpolar in this latitude, their light changes are continuously recorded.

Transits of stars are taken as often as required for the regulation of the sidereal clock and mean time chronometer.

Comet *b* 1902 (Perrine) was observed on seventeen nights between September 12 and November 12. During the first half of October it was a very interesting telescopic object; the principal tail was a long straight ray, on either side of which fainter streams of nebulous matter were seen, giving a distinct three-rayed aspect. The Lunar eclipse on the morning of October 17 was also well seen.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Susse

The following list of nebulæ, &c.—the eleventh of its ki comprises those objects which have been photographed in course of the year 1902. The weather, on the whole, ha been quite so favourable for photographic work as in some p ous years. The 20-inch mirror was resilvered during the summer, and the film is now in excellent condition. Six pl of Perrine's comet were obtained between September 6 October 10, with exposures varying from fifteen to ni minutes.

List of the principal Photographs taken in 1902.

	Approx. R.A. h m	Decl. ° ′	Expos. h m
Neb. H III. 868 Piscium ...	... 0 3	+ 4 3	1 30
Neb. *h* 29 Andromedæ ...	... 0 28	+45 57	1 30
Neb. H II. 707 Andromedæ...	... 0 33	+47 47	1 30
Neb. M. 31 Andromedæ ...	... 0 37	+40 43	1 30
Neb. M. 74 Piscium	... 1 31	+15 16	2 0
Neb. H II. 211 Arietis ...	... 2 28	+28 52	1 30
Region of *Nova* Persei ...	... 3 24	+43 34	2 54 (Jan. 1 30 („
Neb. H IV. 69 Tauri ...	... 4 3	+30 31	1 30
Index Cat. 405 Persei ...	... 5 9	+34 13	1 30
„ „ 410 „ ...	... 5 16	+33 25	1 30
„ „ 417 „ ...	... 5 21	+34 22	1 30
„ „ 419 Aurigæ ...	... 5 24	+30 4	1 30
„ „ 425 „ ...	... 5 30	+32 22	1 6
Neb. M 42 Orionis	... 5 30	− 5 27	0 30 0 15
H's Nebulous Region No. 24	... 5 32	− 4 18	1 30
Star magnitudes near ε Orionis	... 5 35	− 1 16	1 30
Index Cat. 439 Aurigæ ...	... 5 50	+32 0	1 30
H's Nebulous Region No. 28	... 6 1	+ 3 44	1 30
„ „ „ „ 29	... 6 1	−20 27	1 30
Neb. H V. 21 Canis Majoris	... 7 13	−13 2	1 30
Neb. H II. 554 Cancri ...	... 7 56	+16 0	1 30
Neb. H III. 877 Monocerotis	... 8 1	−11 8	1 30
Neb. H III. 488 Hydræ ...	... 9 15	−16 0	1 30
H's Nebulous Region No. 31	... 9 27	−18 27	1 30
Neb. H III. 254 Sextantis ...	... 9 48	+ 2 3	1 30
Neb. H II. 492 Leonis Minoris	... 9 52	+32 51	1 30
Neb. H II. 43 Leonis ...	... 10 8	+23 14	1 30

	Approx. R.A. h m	Decl. ° ′	Expos. h m
28–9 Leonis	10 18	+20 24	1 30
. 27 Hydræ	10 20	−18 8	0 41
77 Leonis...	10 40	+14 17	1 30
101 Leonis	10 55	+14 26	1 30
39–40 Hydræ	10 58	−22 38	1 30
146 Ursæ Majoris ...	11 22	+57 26	1 30
187 Draconis	11 30	+71 5	1 14
. 67 Ursæ Majoris ...	11 50	+59 2	1 30
. 62 Ursæ Majoris ...	11 51	+55 42	1 30 (two)
196 Canum Venaticorum...	12 4	+44 14	1 30
208 Ursæ Majoris ...	12 6	+51 2	1 30
209 Canum Venatic orum...	12 11	+48 26	1 30
)1 Comæ Berenicis ...	12 23	+29 10	1 30
154 Ursæ Majoris ...	12 35	+62 10	1 30
142 Virginis	12 40	+ 3 26	1 30
Canum Venaticorum ...	13 25	+47 43	1 0 0 30 (three) 0 15 („)
297 Virginis	13 32	−17 22	1 30
538 „	14 39	+ 2 6	0 50
? Ophiuchi	17 40	+ 3 13	1 30
n Hercules	18 2	+27 35	1 30
1274–5 Sagittarii ...	18 3	−23 48	0 55
17 Aquilæ...	18 47	− 8 50	2 0
? Draconis	19 2	+55 34	1 30
14 Aquilæ	19 9	− 2 53	2 0
1 Aquilæ	19 39	− 7 3	1 30
878 Draconis	19 41	+55 52	1 30
rs in Cygnus	19 45	+35 30	1 0
2 Cygni	19 51	+28 59	1 30
2 Aquilæ	19 55	+ 1 27	1 30
5 Aquilæ	20 18	+ 6 8	1 30
1 Draconis	20 18	+66 35	1 30
. 142 Aquilæ	20 26	− 2 26	1 30
3 Delphini	20 28	+ 9 35	1 30
1–3 Cephei	20 36	+65 54	1 30
1 Delphini...	20 43	+ 7 21	1 30
· 60 Cygni	20 58	+45 45	2 50
. 74 Cephei	21 0	+67 46	1 30 1 0 (two)

	Approx. R.A. h m	Decl. ° ′	Expos. h m
N.G.C. 7026 Cygni	... 21 3	+47 27	1 30
H's Nebulous Region No. 42	... 21 3	− 1 53	1 30
Neb. H III. 858 Equulei ...	... 21 10	+ 2 25	1 30
N.G.C. 7116 Cygni	... 21 38	+28 30	1 30
Neb. H II. 476 Aquarii ...	... 22 29	−10 52	1 30 2 0
Neb. *h* 2176 Pegasi	... 22 35	+10 30	1 30
Neb. H II. 477 Aquarii ...	... 22 41	−11 32	1 30
Neb. H II. 453 ,, ...	... 22 46	− 6 6	1 30
Neb. H III. 745 Cephei ...	... 22 51	+56 35	1 30
H's Nebulous Regions Nos. 50 and 51	22 57	+25 45	2 0
Neb. H III. 558 Aquarii ...	... 23 3	−16 10	1 30
Neb. H III. 233 Piscium ...	... 23 48	+ 7 25	1 30
Neb. *h* 2302 Cassiopeiæ ...	... 23 59	+67 7	2 0 (two)

Comet *b* 1902 (Perrine) 90ᵐ, 60ᵐ, 45ᵐ, 60ᵐ, 15ᵐ, 52ᵐ.

Mr. Saunder's Observatory, Crowthorne, Berks.

With the assistance of Mr. J. A. Hardcastle, F.R.A.S. progress has been made with the measurement of two of the Lunar photographs kindly lent by M. Loewy. Much work done during the early part of the year had to be rejected, as serious errors were found in the réseau employed. This réseau was made in England, and had been kindly presented to the University Observatory, Oxford, expressly for this work, the diameter of the Moon on the Paris plates being such as to require a réseau larger than those in use for the astrographic plates. Finally a new large réseau was obtained from M. Gautier, and has given entire satisfaction. A further delay was caused by the slipping through 0·003 inch of the copy of this réseau attached to one of the plates during the progress of the measurements. (See *Monthly Notices*, vol. lxiii. p. 73.) The epoch at which the greater part of the shift occurred has been ascertained, and suitable corrections applied to the readings. It is hoped that work now in progress will determine the epochs at which the rest of the shift occurred, and enable the measures of 500 points made on this plate to be saved; also that the method now adopted for securing the réseau will prevent the occurrence of similar accidents in the future. On the other plate some fifty points have been measured and the plate constants found. This work has been rendered possible by a grant made by the Government Grant Committee of the Royal Society.

The telescope has been employed chiefly on the Moon. A series of measures has been made of the white spot surrounding

the crater Linné, which it is believed will confirm the announcement made by Professor W. H. Pickering that the diameter of this spot varies with the progress of the Lunar day. Progress has been made with the map of *Ptolemæus*, and the telescope has also been used for comet-sweeping.

Mr. W. E. Wilson's Observatory.

In the early spring a set of duplicate photographs were taken for the search for an ultra Neptunian planet. These were carefully compared with the set taken the previous year, but with a negative result. The plates cover the region of the sky in which the researches of Forbes, Todd and Lau, all locate the position of such a planet.

The weather during the year has been even worse than the previous year, and practically no work could be done with the 24-inch reflector. Rain fell on 246 days, and the quantity of cloud was abnormal. During the summer the new pyrheliometer was calibrated with Angström's standard instrument, and it now gives a reliable record of the solar radiation.

Melbourne Observatory.

Meridian Observations made with the 8-inch Transit Circle.

	R.A.	N.P.D.
Azimuth stars	298	138
Clock ,,	414	...
List ,,	734	740
Zodiacal ,,	1083	1077
	2529	1955

The list stars were, as in previous years, selected from the Melbourne plates of the Astrographic Catalogue, to be used as standard reference stars for the reduction of those plates.

The zodiacal stars were selected from the list of heliometer comparison stars published by Sir David Gill, 1901 April 2. The observations covering the full list will be completed by the end of the current year.

Reductions.—The separate results and annual catalogue for 1901 have been completed, and the reductions of observations made in 1902 are nearly up to date.

The total number of standard stars for the reduction of the Astrographic Catalogue plates which have been completely observed with the 8-inch transit circle three times or more is 085.

Astrographic Operations.—

Chart plates with triple exposures of 30^m each ...	143
Catalogue plates (second series)	139
Test plates on south polar regions	43
Test plates on Oxford type regions	12
Test plates for centre, focus, trails, &c.	32

Eleven chart plates and two catalogue plates were rejected as defective.

The state of this work to December 31st, 1902, is as follows:—

Chart plates with triple exposures of 30^m each, passed as satisfactory	244
Chart plates with single exposure of 60^m each (complete)	—
Catalogue plates (complete)	—
Catalogue plates (duplicate series)	139

A careful examination of the contact prints on glass, of the series of our chart plates with single exposure of 60^m, which were obtained towards the end of 1901, has shown that these positives are very defective, the faults arising chiefly from impurities in the water used for washing the original negatives, and dust, settled on them while drying.

In order to remedy these faults as far as practicable the system has been adopted of using only thoroughly filtered water for washing the plates, and drying in a closed box over a tray containing pieces of chloride of calcium. With these precautions we now obtain much better results.

Other Observatory work during the current year comprises, as in previous years—

The State weather service, with the control of 800 recording stations.

The Time service.

The Tide service.

Terrestrial magnetism, including the carrying out of the full programme prescribed by the Royal and Royal Geographical Societies for co-operation in 1902–03 with the Antarctic Expeditions, and the measurement and reduction of some 6100 daily magnetic curves covering the period 1875–1880.

Registration of seismic disturbances by means of the Milne horizontal pendulum, which has been regularly at work since March 1902, and of seismic disturbances reported by observers at various recording stations in the Commonwealth.

The reduction of arrears of astronomical observations, cloud photography, and climatological statistics, and many other minor duties for public local requirements.*

The State standards of Weights and Measures, and all the stock of copies for issue to the Municipalities; balances, apparatus,

* Rating of chronometers, and testing nautical, meteorological, and surveying instruments.

and accessories for verification and adjustment were last September transferred to the Observatory, and all technical work related to the Administration of the Victorian Law on Weights and Measures has since formed part of the duties of this Institution, by order of the Government.

There is some hope that the Metric system may soon be introduced in Australia.

No changes in the staff have taken place. The position of Chief Assistant is still vacant, and there seems to be no prospect of filling it this year.

Measurement of the Sydney and Melbourne Plates of the Astrographic Catalogue. Joint Report for Sydney and Melbourne.

This work was carried on by the Measuring Bureau at the Melbourne Observatory, using the Gill-Repsold measuring instrument, and the Melbourne filar micrometer-machines, as in previous years. The second Gill-Repsold measuring instrument, which was ordered in 1900, reached the Observatory at the end of last September. This second apparatus is similar to the first in design, dimensions, and excellence of workmanship, and is highly satisfactory in every respect.

A new room for the astrographic measuring bureau was erected in the course of the year, and was ready for occupation by the end of December. This interfered a little with the progress of the work ; but the new room is a great improvement, and the work is now carried on far more comfortably and satisfactorily than in the old building, which was far too small.

The measurements made during the year ending December 31st, 1902, were as follows :—

83 Sydney plates, containing 24,142 stars, completely measured in the direct and reverse positions.

194 Melbourne plates, containing 58,988 stars, also completely measured in the two positions.

The total numbers of plates completely measured up to date are as follows : -

224 Sydney plates, containing 131,061 stars, or an average of 585 stars per plate.

293 Melbourne plates, containing 83,482 stars, or an average of 285 stars per plate.

Perth Observatory, West Australia.

Progress in the Astrographic work has not been so rapid as was expected, for two reasons :

Owing to some difficulty in procuring reliable plates for the chart series no work was done with this instrument between February 6 and April 24 ; and in September the Government

Astronomer was officially informed that all astronomical w not required for local purposes must cease on December This naturally caused disorganisation. No fresh plates w ordered and each of the officers obtained his accumulated le of absence; so that very little has been done during the l three months. Notwithstanding these serious interrupti 52 triple chart and 96 catalogue plates have been taken.

When the proposed discontinuance was reported the Ro Society made representations to the British Government, and a result the matter will probably be reconsidered by the W Australian Government, and it is hoped that now they rea its importance they will see their way to authorise the com tion of the work. Just at present, however, nothing is definit settled.

Measurement of Plates.—Unfortunately this has not b commenced, and there seems little chance of the Perth Obs vatory being able to undertake it.

Transit Circle.—Work with this instrument has progres steadily. The working scheme includes three stars per deg where possible, or twelve per plate, for zones 31° to 40°. E star is to be observed three times in R.A. and N.P.D. (usi four microscopes), and it is desired to take two degrees per ye The zones 31 and 32 (31° 0′ to 33° 0′ south declination) completed, with the exception of a few scattered observations, a reduced. In a number of cases three suitable stars could not found in the degree, and the total number for the above 1 zones is 1632.

At the request of Sir David Gill the zones 40° and 41° a now being taken, and in these 236 stars have been complet observed. The reductions are well up to date, but nothing is present going through the press.

The total number of observations made with the tran circle during the year is

Level determinations	209
Azimuth	247
Collimation	40
Nadir	177
Observations of R.A. (zone stars)	5168
,, N.P.D. (zone stars)	5214
,, R.A. (clock stars)	967
,, N.P.D. (clock stars)	57

Time Service.—This worked satisfactorily during the ye In addition to the time ball at Fremantle a time gun has b established both there and in Perth.

Meteorological. The usual routine has been continued, a the forecasts have again been very successful. The ann

report for 1901 is printed and will shortly be distributed. The Milne seismograph has worked satisfactorily throughout the year, and abstracts of the records have been forwarded to Professor Milne.

Lovedale Observatory, Cape Colony. (*Dr. A. W. Roberts's.*)

The work of this observatory has been, as in previous years, the observation of variable stars south of declination −30°.

Owing to the unfavourable weather during 1902, the observations made were not so numerous as in the previous year.

The following is a summary of work done :

	Stars.	Observations.
Algol variables	5	503
Rapid variables	1	21
Short-period variables	22	369
Long-period variables	68	2696
Suspected variables	10	90
Total	106	3679

The observations of Algol variables were taken for the most part with the prismatic equatorial recently constructed by Cooke, and the other observations either with the 1-inch or the 3-inch telescope.

The mode of observation is that followed in previous years. With both the 1-inch and 3-inch telescopes, two eye-pieces, one giving a direct and the other a reverse position of the field, are used.

In the case of the prismatic telescope, each observation is the mean of four or six pointings, the field being situated through 90° or 60° respectively. As a result of this system of observing, very accordant light curves of the southern Algol stars have been secured.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, N.S. Wales.

The work done at this observatory during 1902 is quite equal to that of the year preceding. It is classified as follows :

Meridian Department.—

Nights on which the time was determined		103
Transits of stars with a declination not exceeding 40°		422
Transits of stars of high declination for azimuth		91
Separate determinations of	level error	277
	collimation error	29
	azimuth error	68

Like its predecessor, the year 1902 was a very dry one, bei as regards rainfall, the driest recorded at the observatory forty years. The level disturbances were therefore not so g as usual.

Extra-meridian Department.—The following micrometer c parisons were made with the equatorials:

Objects Compared.	Nights of Observation.	Number of Comparisons.	Number of Comparison S
(2) Pallas...	11	134	5
(4) Vesta	13	124	6
(8) Flora	17	176	10
(42) Isis	25	270	16
(164) Eva...	7	65	7
Comet *b* 1902 (Perrine) ...	7	51	10

Comet *b* 1902, was still under observation at the close of year, and will probably be followed till it again becomes visi in northern latitudes. Double-star observations were made eighty-two different dates, and the number of pairs measured fifty-four of the most interesting objects selected from Inn Reference Catalogue. The work involved 1765 settings f position-angle and 1503 double settings for distance. A lo series of measures of α *Centauri* was sent to Dr. A. W. Roberts, South Africa, in accordance with his request. In addition to t work already mentioned, a few observations were made of lun occultations of stars and of phenomena of *Jupiter's* satellit The usual rainfall and maximum and minimum temperat observations have also been carried on throughout the year.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1902.

Fifty new planets were discovered during the past year, as follows :

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1902.	Discoverer.	Place of Discovery.
HP	481	...	Feb. 12	Carnera	Heidelberg
HR	...	...	Mar. 3	Wolf	,,
HT	482	...	,, 3	,,	,,
HU	483	...	,, 4	,,	,,
HW	...	...	,, 6	,,	,,
HX	484	...	May 7	,,	,,
HY	...	...	,, 7	,,	,,
HZ	485	...	,, 7	Carnera	,,
JA	...	...	,, 7	,,	,,
JB	486	...	,, 7	,,	,,
JC	...	...	,, ,,	,,	,,
JD	...	...	,, 11	,,	,,
JF	...	...	(1899 June 9)	Pulfrich	,,
JG	...	...	1902 June 26	Wolf	,,
JL	487	Venetia	July 9	Carnera	,,
JM	...	...	Sept. 2	,,	,,
JO	...	...	,, 3	Wolf	,,
JP	...	...	,, 3	,,	,,
JQ	...	...	,, 3	,,	,,
JR	...	...	,, 3	,,	,,
JS	...	...	,, 7	,,	,,
JT	...	...	,, 26	Carnera	,,
JV	...	...	Oct. 7	Wolf	,,
JW	...	...	,, 7	,,	,,
JX	...	...	,, 7	,,	,,
JY	...	...	,, 24	,,	,,

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1902.	Discoverer.	Place of Discovery.
JZ	...	...	Oct. 24	Wolf	Heidelberg
KA	...	...	,, 25	Dugan	,,
KB	...	...	,, 25	Wolf	,,
KC	...	...	,, 25	,,	,,
KD	...	...	,, 25	,,	,,
KF	...	...	,, 25	,,	,,
KG	...	...	,, 25	,,	,,
KH	...	...	,, 25	,,	,,
KJ	...	...	Nov. 4	Dugan	,,
KL	...	...	Oct. 25	Wolf	,,
KM	...	...	Nov. 20	,,	,,
KN	...	...	,, 20	,,	,,
KO	...	...	,, 21	,,	,,
KP	...	...	,, 21	,,	,,
KQ	...	...	,, 21	,,	,,
KR	...	...	,, 21	,,	,,
KS	...	...	,, 21	,,	,,
KT	...	...	,, 21	,,	,,
KU	...	...	Dec. 2	Charlois	Nice
KV	...	...	,, 23	Wolf	Heidelberg
KW	...	...	,, 24	,,	,,
KX	...	...	,, 24	,,	,,
KY	...	...	,, 24	,,	,,
KZ	...	...	,, 24	,,	,,

The number of discoveries is far the largest on record in any year, but it is possible that some of the recent discoveries may prove to be planets already known. The planets provisionally designated by the following letters proved to be identical with known planets :—HL with 358 *Apollonia*, HO with 458, HQ with 93 *Minerva*, HS with 359 *Georgia*, HV with 72 *Feronia*, JH with 486, JJ with 451 *Patientia*, JK (probably) with 470 *Kilia*, JN with 311 *Claudia*, JU with 106 *Dione*, KE with 19 *Fortuna*, KK with GT, each being probably identical with (156) *Xanthippe*.

Planet GL, unnumbered at the date of the last Report, has since received the permanent number 480.

The following planets do not receive permanent numbers, not having been sufficiently observed :—HM, HR, HW, HY, JA, JC, JD, JF, JG, JM. The discovery of JE was cancelled as erroneous.

The discovery of JF is a triumph for the stereo-comparator, Dr. Pulfrich having detected the planet by its aid on a plate

aken three years earlier, on which the trail had escaped letection

The following planets have been named : –359 *Georgia*, 472 *Roma*, 475 *Ocllo*, 477 *Italia*, 478 *Tergeste*.

The interesting planet *Ocllo*, whose orbit is the most ccentric of the whole family, has been recovered at the present pposition, being of the fourteenth magnitude.

Several observations of *Eros* were obtained in Europe and merica a few months ago ; during its opposition it is in such igh south declination that it is out of reach of northern bservers. A. C. D. C.

The Comets of 1902.

The comet history of the year is practically limited to the bservations of four comets.

Comet 1902 *a* was discovered by Mr. Brooks, of Geneva, New ork, on April 14. Situated in the constellation *Pegasus*, obervations were possible only in the morning sky, and the rapidity rith which the comet approached the Sun considerably curtailed hese. It is to be feared that the comet was insufficiently bserved, and that the true form of the orbit will remain loubtful. The earlier course of the comet, prior to discovery, ad been through *Cygnus*, where the opportunities for detecting t, if more favourable in position, were discounted by the greater aintness of the object. This comet is reported to have had a ail some twenty minutes long, and in a photograph of comparatively short exposure taken by Dr. Max Wolf this tail is shown s a fan-like appendage with the southern concave border noticeably brighter than the northern. There is scarcely any recognisable nucleus, but the object is very feebly impressed on the photographic plate.

The second comet (1902 *b*) was discovered by Mr. Perrine, of the Lick Observatory, on August 31, and independently by M. Borrelly at Marseilles, a night or two later. It was described by Mr. Perrine as a slightly elongated nebulosity, four minutes in diameter, with a well defined nucleus and some evidence of a tail. This object, found in *Perseus* and travelling northwards, was easily followed, and its continually increasing brilliancy attracted general attention. A rapid movement to the south in October carried it into the southern hemisphere, where it has since been observed by Mr. Tebbutt and others. It is not impossible that the comet will be seen again in these latitudes in February or March, when it will pass through *Canis Major*, and should have a brilliancy approximately equal to that of the time of discovery. The observations are well represented by a parabola, but an interesting feature in the orbit is the near approach it makes to that of *Mercury*. The comet was separated from the planet, when nearest, by about 0·02 R, a close approach, but scarcely sufficient to disturb noticeably the parabolic velocity.

Numerous observations have been made of the physical appearance of the comet, and many photographs have been taken. For the general results of this kind of observation it will be sufficient to refer to the illustrated paper communicated by the Astronomer Royal to the November number of the *Monthly Notices*, in which number is also given an account by Dr. Max Wolf of an attempt to obtain a stereoscopic effect by exposing plates at slightly different times.

The third comet, known as *c*, was discovered previous to that of Perrine, and passed its perihelion some months earlier; but, owing to an unfortunate circumstance, intelligence of the discovery did not reach Europe till September. On July 22, Mr. Grigg, of Thames, New Zealand, suspected a comet in the constellation *Leo*. Examination on subsequent evenings confirmed this suspicion, and he gave notice to Mr. Baracchi and others. Mr. Baracchi did not receive information till August 6, and made careful search over a wide area at the earliest possible opportunity, but without success. He therefore awaited confirmation or fresh information from some other source; but unfortunately the comet was seen only by Mr. Grigg. The observations are rough, but Mr. Grigg has computed a set of elements from his data, which show that the comet when at its brightest must have passed through *Taurus* and *Gemini* in the preceding June. In these constellations it was scarcely likely that the comet would have been seen in northern latitudes. It was decreasing in brilliancy when seen by Mr. Grigg at the end of July, and under the adverse circumstance of doubtful position and fading illumination it was scarcely likely that it would be recovered when intelligence reached this country.

The last comet discovery of the year was made by M. Giacobini, of Nice, to whom we have been indebted for the detection of several faint comets. This one is also a faint object, but is particularly interesting on account of its great perihelion distance (2·8 R). With the single exception of the comet of 1729 there is no instance of a comet remaining at so great distance from the Sun. Necessarily the motion is slow, and any variation in brilliancy scarcely perceptible. It will not reach its perihelion till next March, and observations will be possible for some time to come. An accurate ephemeris has been prepared by Dr. Ristenpart, especially adapted to a plan which he has suggested as desirable for the reduction of extra-meridional observations of comets. Since the suggestion offers some advantages, and is likely to be gradually adopted, too wide a publicity cannot be given to the proposed innovation, in order to avoid subsequent confusion in the definitive determination of orbits.

Some other comets have passed through perihelion without being seen. Among these may be mentioned Swift's comet of 1895, and another known as Tempel-Swift. The former of these was probably in perihelion in November, and observations might have been made in the summer. But the conditions for

erving were not so favourable as in 1895, and the extreme itness of the comet has baffled the search. The second is the et discovered by Tempel in 1869, and re-discovered by Swift 880. It was seen in 1891 by Barnard. An ephemeris for apparition was prepared by M. Bossert, but apparently out success. August seemed a fairly favourable time to ver it, and in this month Dr. Max Wolf applied the photo-hic method to secure its detection. Up to the present it not been seen.

Ir. Lindemann's offer to subsidise inquiries in the matter of t orbits whose definitive elements have not been determined been effective, and several sets of elements of ancient ts have been added to our catalogues, mainly through his rosity.

Progress of Meteoric Astronomy in 1902.

anuary Meteors.—On January 2, during intermittent watches unting to two hours, Mr. T. W. Backhouse, at Sunderland, rved 24 meteors, including 18 *Quadrantids*. On the follow-night, in $1\frac{3}{4}$ hour, 10 meteors, including 5 *Quadrantids*, were . On January 2, $9^h\ 52^m$ to $10^h\ 37^m$, Mr. J. H. Bridger, at borough, counted 6 meteors (3 from *Quadrans*).

pril Meteors.—The *Lyrids* appear to have escaped observa-, the moon being full on April 22.

uly Meteors.—Mr. R. M. Dole, Ogunquit, Me., U.S.A., ched for the *Aquarids* on July 30, 8^h to $14^h\ 45^m$ and found shower in rather strong evidence, 62 of its meteors being ted in the $6\frac{3}{4}$ hours over which observations extended. ween 12^h and $14^h\ 45^m$ the rate of apparition was 1 every ninutes. The meteors were mostly slow and faint, with long ns.

ugust Meteors.—There was little interference from moon-t, but cloudy weather was very prevalent over the west of land, though the sky seems to have been generally favourable he eastern counties. At the Royal Observatory, Greenwich, following results were obtained :

Date.	Time of Watch. h		h	Duration.	Observers.	No. of Meteors.	No. of Perseids.
August 9	10	to	15	5	3	28	22
10	9	,,	16	7	3	106	94
11	$9\frac{1}{2}$	,,	$13\frac{1}{2}$	4	3	74	67
12	9	,,	16	7	3	101	92
13	10	,,	12	2	1	23	21
Totals, five nights				25	...	332	296

Ir. G. M. Knight, London, watched the sky on seven nights

between July 31 and August 10, and counted 539 meteo these 239 were observed on August 10 in $3\frac{3}{4}$ hours.

Mr. A. King, Leicester, obtained observations l July 27 and August 12, and during watches extendi $11\frac{1}{2}$ hours recorded 98 meteors (32 *Perseids*). "The m seemed to occur on August 11 or 12, probably the latter

Mr. Backhouse, Sunderland, saw 33 *Perseids* in $1\frac{1}{4}$ hour on August 11, between 11^h and 13^h 50^m.

At Bristol, owing to unusually inclement weather, th could only secure brief observations on five nights l August 2 and 14, when 53 meteors were seen in about watching.

Mr. C. P. Olivier, University of Virginia, U.S.A., on August 10, between 12^h 33^m and 16^h 8^m, and 70 meteors (42 *Perseids*). On August 11, between 13^h 16^h 8^m, there were 102 meteors (76 *Perseids*). Rate of August 10, 1 in 5 minutes; August 11, 1 in 1·9 minute.

Mr. Dole, Ogunquit, Me., describes the *Perseid* dis "very active" in 1902, with maximum on August 12, He recorded the following numbers:

	h m	h m	
August 12	11 20 to	15 21	261 *Perseids*
,, 13	11 40 ,,	15 18	176 ,,

Reports have been received from a considerable nu other stations, and they prove that the *Perseid* show a fairly rich one—probably stronger than the average—t maximum occurred on the morning of August 13, and t centre of radiation exhibited its normal displacement E.N.E., as observed on successive nights. The followi some determinations of the radiant position:

Date. 1902.	Radiant. α	δ	Meteors.	
August 1–3	37°	+ 55	26	G. M. Knight
3	$40\frac{1}{2}$	+ 54	6	C. L. Brook.
4 5	40	+ $55\frac{1}{2}$	12	G. M. Knight.
8	$42\frac{1}{2}$	+ $54\frac{1}{2}$	11	H. J. Townshe
8 10	44	+ 53	7	C. L. Brook.
9	38	+ $56\frac{1}{2}$	...	Herr Koss.
10	39·5	+ $56\frac{3}{4}$	42	C. P. Olivier.
10	44	+ 58	9	A. King.
10	$44\frac{1}{2}$	+ 57	43	G. M. Knight.
10	45	+ $58\frac{1}{2}$	15	W. F. D.
10	$45\frac{1}{2}$	+ $54\frac{1}{2}$	...	Herr Koss.
11	$46\frac{3}{4}$	+ $56\frac{1}{4}$	76	C. P. Olivier.
12	47	+ $58\frac{1}{2}$	9	W. F. D.
48	48	+ $56\frac{1}{2}$	6	A. King.

Professor J. Lycova, of the Jourieu Observatory, Dorpat, photographed 7 meteor trails on 1901 August 11, of which 5 were *Perseids*, indicating the radiant at α 43° 55′·8, δ +57° 10′·3. On August 12 he found the radiant evidently slightly east of that position.

Meteoric Showers in September.—During the first week of the month 116 meteors were seen at Bristol during 18 hours of observation. Two pretty conspicuous showers of *Polarids* were seen, and there were active displays of η *Aurigids* and *Tria-gulids*.

October Meteors.—Cloudy weather and the light of a full moon appear to have effaced the *Orionid* shower.

November Meteors.—Though the *Leonids* of the three years 1898, 1899, and 1900 disappointed every eye, the hope was encouraged that, as the shower had exhibited a decided intensification in 1901, there would be a pretty strong recurrence of it in 1902. Moreover the latter year was suggested as favourable by its return, owing to the fact that brilliant displays had been witnessed in 902, 1002, 1202, and 1602, and that exactly three revolutions of the swarm were performed in a century. The meteors were therefore looked for in 1902 November with almost equal enthusiasm to that shown in previous years, though the Moon most inopportunely became full at the very time when the maximum was expected. Other conditions proved unfavourable; overcast skies just at the important period appear to have veiled the meteors from the majority of observers both in England and America. At stations, however, where suitable views could be obtained there was no sign of an abundant display; only a few *Leonids* could be seen interspersed with the ordinary "sporadic" shooting stars. Reports from sixty stations in America affirm that practically no shower of *Leonids* was seen. Before sunrise on the morning of November 13 the *Leonid* radiant seemed quiescent or nearly so, as observed at Bristol and by Mr. A. King at Leicester. Cloudy nights then intervened, but on November 18, between 2 and 3 A.M., some 8 or 10 meteors were seen by Mr. J. R. Henry, of Dublin, "flashing from *Leo*," but their identity as true *Leonids* is somewhat questionable, though the date is certainly not too late for belated members of the stream. On November 14, from midnight to $15^h\ 30^m$ E.S.T., Mr. Wendell and assistants at Cambridge, Mass., watched a sky partly involved in cloud and haze and only counted 5 meteors. At Mexico City, Mexico, Mr. L. G. Léon maintained a look-out on November 14, 2 to 4 A.M., and states that in the beautifully clear, moonlit sky he recorded 18 *Leonids*. It is obvious, however, from the chart of tracks published in *Popular Astronomy* (1903 January) that very few of these meteors were genuine *Leonids*. It is often difficult—sometimes impossible—to identify the latter objects from the meteors of contemporary showers directed from radiants near the Sickle of *Leo*.

Of the *Andromedids* (November 23) and *Geminids* (Decem-

ber 10–12) little or nothing appears to have been observed in 1902. The year generally was unfavourable for meteoric observation, owing to the unusual amount of cloud that prevailed and to the fact that bright moonlight virtually overpowered several of the principal showers.

The following is a list of real paths of bright meteors observed in England during the past year :

Date. 1902.	G.M.T. h m	Brightness.	Height at First. Miles.	Height at End. Miles.	Length of Path. Miles.	Velocity per Sec. Miles.	Radiant Point. α ° δ °	Observers.
May 27	12 22	$1\frac{1}{2}-$ ♀	63	39	120	24	282 − 24	2
July 13	10 30	= ♃	89	51	51	26	315 + 31	60
27	11 36	4	71	52	45	33	351 + 3	2
Aug. 21	14 2	= ♃	65	33	611	15	283 − $10\frac{1}{2}$	20
Sept. 25	7 34	> ♀	88	57	34	> 100	254 + 46	2
Oct. 15	7 47	♀	62	54	130	37	150 + 43	3
Dec 2	7 20	> ♀	63	42	31	14	43 + 22	2

A fine meteor was seen by Professor A. S. Herschel, Captain P. B. Molesworth, and other observers on July 15, $9^h\ 32^m$. The former determined its radiant at 236° 13°, height 60 to 38 miles, observed path 51 miles, and velocity 17 miles per second.

Comparatively few new determinations of radiants have been obtained during the year. While watching the *Perseids* on August 10 Mr. Knight recorded 15 *β Andromedids* from a centre at 19° + 20½°. The following radiants were the principal ones derived from observations at Bristol, July to September. In some cases a few meteors recorded in previous years were combined with those seen in 1902, in order to strengthen the positions and ascertain them more accurately :

Year		Radiant. α ° δ °	Meteors	Notes
1885 1902	July 5 13	22 + 22	7	Swift, streaks.
1887 1902	July 7 —	10 − 45½	6	Swift, streaks. Very early Perseids.
1885 1902	July — 21	32 − 32	7	Swift, streaks.
1902	Aug. 24 Sept. 7	74 − 21	7	Swift, streaks.
1885 1902	Aug. 25 Sept. —	353 − 1	15	Slow, long paths.
1902	Aug. 26 Sept. 7	337 − 51½	12	Swift.
1902	Sept. 3 7	18 − 55½	8	Swift.
1902	Sept. 3 7	32 − 37	8	Swift, short.
1887	Sept. 7 23	10 − 13	12	Swift, streaks.
1885 1902	Nov. 2 —	34 − 3	13	Very slow.

[illegible]—At $10^h\ 55^m$ G.M.T. on the morning of Nov. 12, when the Sun was shining and the

air still, strange sounds of a very loud and unusual character were heard over East Tyrone, Ireland, by many persons, who were much alarmed and considered them the accompaniment of an earthquake. The Rev. E. F. Campbell says : "The sound seemed to be very deep in the heavens ; to the east it appeared to be far above thunder distance and about half as loud. It lasted from thirty to sixty seconds, and I can only describe it as being like the whirring of a very large motor with a deep tone." Another observer at Market Hill, Co. Armagh, describes it as "a great rumbling sound which lasted about eight seconds. It was a full round booming pervaded by a regular wavy rumbling. A boy eleven years of age, working in a garden, when he heard the noise ran away and said the ground was shaking." At about the same time (probably a few minutes previously) a pear-shaped fireball with a tail was seen by Mrs. Martin, of Dunsink, Co. Dublin, passing overhead and falling low towards the north horizon. A singular feature of the event is that a rushing noise above her head attracted Mrs. Martin's attention to the meteor, and that this sound continued to be distinctly heard during the three or four seconds occupied in the descent of the object. It was also seen by Master R. Fitzmaurice, of Carlow, and he says it flashed into sight in the N.E. and left a long train behind. The radiant point of the meteor was probably in *Aquarius* or *Pisces* in the southern sky, and the disruption of the object must have occurred comparatively near the Earth's surface in the district of Dungannon and Lough Neagh, though none of the fragments appear to have been found.

Observed Fall of a Meteorite.—The most important meteoric event of the year occurred on September 13, $10^h\ 55^m$ G.M.T., when a meteorite fell at Crosshill, near Crumlin, and about twelve miles west of Belfast, Ireland. The stone has been acquired for the British Museum, and the explanatory label * attached to the case containing it gives all the essential particulars of the event in a concise form :

"On Saturday, September 13, at 10.30 A.M.,† a loud noise as of explosions was heard at various places on the western side of Belfast ; among others, Antrim, Crumlin, Lisburn, Moira, Lurgan, and Pointzpass. Of these Antrim and Pointzpass are thirty miles apart. One observer at Crosshill at first thought that the noise was due to the bursting of the boiler in the mill at Crumlin a mile away ; another thought that a train had run off the line. Two or three distinct detonations were heard. The detonations were followed by another sound likened to that made by escaping steam ; other observers describe it as a rattling noise, similar to that made by a reaping machine, but much louder. Two men, Walker and Montgomery, were at the time stacking

* Written by Mr. L. Fletcher, F.R.S. A very interesting and illustrated description by the same author appeared in *Nature*, 1902 October 9.

† Local time.

hay at Crosshill. The former was on the top of the nearly finished stack, and immediately after hearing the noise saw from this lofty point of view something whirl into the adjacent corn field.* The exact spot was indicated by a cloud of dust which at once rose above the standing corn. It was only twenty yards distant from a tree on which a third man, Adams, was at work gathering apples. It was found that a deep hole had been made in the soil. Adams went for a spade, and within a quarter of an hour of the fall extracted from the hole a black, dense stone, which had penetrated to a depth of eighteen inches and had then been stopped by a much larger stone lying in the soil. The black stone was hot when extracted, and is said to have been warm even an hour later. Before being cut to show its interior the stone weighed 9 lbs. $5\frac{1}{2}$ oz., and was $7\frac{1}{2}$ inches long, $6\frac{1}{2}$ inches wide, and $3\frac{1}{2}$ inches thick. The stone consists of a grey material covered with a thin black crust. Such a crust is always found on meteoric stones. The surface of the meteorite, owing to the immense compression of the air in front of the swiftly moving body, becomes hot enough to be luminous, and is well scorched. The pressure of the air on the front of the meteorite continues to increase until at last the material yields and breaks up with violent detonation. If the fragments thus produced are still travelling with great speed the new surfaces likewise become encrusted, though not as much as the earlier ones. The form of the Crumlin stone is distinctly fragmental, and one large surface of fracture well illustrates this stage of later scorching. The meteorite chiefly consists of stony material, probably a mixture of olivine and enstatite; through it are dispersed grains of a metallic alloy of iron and nickel. Here and there are small nodules of the bronze coloured mineral troilite, a compound of iron and sulphur not found as a native terrestrial product."

The stone has not yet been submitted to chemical analysis.

Previous and most recent falls of meteorites occurred in the United Kingdom as follows:

1881 March 14. Stone $3\frac{1}{2}$ lbs. in weight fell on a railway siding near Middlesborough, Yorks.

1876 April 20. Mass of iron $7\frac{1}{2}$ lbs. in weight fell at Rowton, near Wellington, Shropshire (*Monthly Notices*, xxxvi. pp. 205-6).

Great Meteorite of Sinaloa, Mexico.—The *American Geologist* for 1902 October contains a paper by H. A. Ward, of Rochester, N.Y., descriptive of the above object. He visited Bacubirito, an old mining town in the Rio Sinaloa, in lat. 26° N. and long. 107° W., and the great meteorite was located about seven miles south of that place on a farm named Ranchito. Its appearance was that of a long monstrous boulder of black iron, which

* The meteorite fell on the farm of Mr. Andrew Walker, and he states that it must have descended perpendicularly, or nearly so, according to the shape of the hole, and the corn standing round was not beaten down in any way.

be still burrowing to hide itself from the upper world. was removed from round the meteorite, and its dimen- e then ascertained to be: length, 13 ft. 1 in; width, ; thickness, 5 ft. 4 in. Mr. Ward concluded that this probably the largest of its kind in existence, and esti- weight as approximately fifty tons. The application of ught out the Widmanstatten figures in a beautiful Professor J. E. Whitfield made an analysis of the s follows:

Specific gravity ... ... 7·69			
... ...	88·944	Sulphur ...	0·005
el ...	6·979	Phosphorus ...	0·154
lt ...	0·211	Silicon ...	trace

Determinations of Radiants.—Professor D. Eginitis, of gives a list of radiants in *Astronomische Nachrichten*,) of which are probably new. He mentions that in 1900 the maximum of the *Perseids* occurred on August 11. tis specially remarks upon the fact that the principal apparently exhibit multiple radiants. It will be remem- it Mr. J. W. C. Herschel attributed a similar character *yrid* shower of 1901 (*Monthly Notices*, lix. p. 564). In regular meteoric observers have met with instances of d radiation. This feature obviously requires further tion, but it may well be regarded as a necessary outcome aterials employed. Observational inaccuracies, erratic f perturbed meteors, and mistakes in apportioning o their various radiants, must sometimes induce indefinite , and the path intersections will indicate a number of us foci. But careful observations of the same showers l years will prove that the latter are not due to concen- eor streams, but are rather an effect of the accidental of positions depending upon uncertain data.

ric Section of the British Astronomical Association.— annual reports have been published (the last in 1902 nd they contain a mass of useful information in the ables and descriptive matter, illustrative of and resulting teoric work since 1890. The twelfth report is on the iblication by the present director, Mr. W. E. Besley.

W. F. D.

Solar Activity in 1902.

ough the solar activity in 1902, as evidenced by the and areas of Sun-spots, has not been great, there can be ; that the actual minimum is past, and that a new cycle nctly begun. This is clearly seen in the diminution of hout spots, the 81 per cent. of 1901 having fallen to

about 72 per cent. in 1902. The percentage numbers of spotless days from the Greenwich records for 1898, 1899, and 1900 were 13·5, 33·8, and 53·1 respectively; so that, in spite of this improvement, 1902 must still rank as an exceedingly quiet year. The mean daily spotted area has increased markedly over that for 1901, being very nearly double; between 50 and 60 millionths of the Sun's visible disk as compared with 29 for 1901, but falling much short of the 75 registered in 1900. The number of separate groups has increased in an even larger proportion than the mean area, being 37 as against the 15 of 1901. The principal groups of the earlier part of the year were three in number. The first of these ran its course from January 5 to January 15, and was a group of the type which increases in actual as well as in apparent size the more fully it is presented towards the Earth. The second, seen from March 3 to March 14, was the largest group of the year. The third, from May 24 to June 4, was much smaller. The intervals between these times of disturbance were very quiet; from March 15 to May 4 inclusive, a period of 51 days, no spots were observed, and from June 5 to September 17 it was only occasionally that spots were seen, and these were always very small, faint, and short-lived. But the appearance of a new group on September 18 marked the commencement of a more regularly active period, more than half the groups of the year appearing on or after that date; and though these later groups never equalled that of March 3–14 in size, there has been scarcely a day from September 18 to the date of this report when the sun has been wholly free both from spots and from faculæ.

The faculæ in 1902 have shown a much more unmistakable increase than the spots. Their mean daily area had fallen from 337 in 1899, and from 180 in 1900, to 29 in 1901, but in 1902 it reached practically the same level as in 1900. M. Guillaume, from the observations made at the Lyon Observatory, indeed puts the total faculous area higher than in 1900; viz. 97·5 thousandths of the visible hemisphere in 1902 as against 81·2 in 1900; whilst the number of distinct groups was 363 in 1902 as compared with 210 in 1901, and 134 in 1900.

The distribution of spots in heliographic latitude has also been characteristic of the beginning of a new cycle. Most of the groups have formed between the 20th and 30th parallels: one group very nearly on the 40th. But three or four groups have been seen much nearer the equator; notably the first group of the year, that of January 5 to 15, which had its centre in S. latitude 8°.

The distribution of the faculæ in latitude has not altered much since the preceding year. M. Guillaume's figures show that there was a remarkable change from 1900 to 1901: only 20 per cent. of the groups having a higher latitude than 40° in the former year, whilst more than 40 per cent. exceeded that latitude in the later. This proportion was almost exactly preserved in 1902.

Of the two hemispheres the northern was much the more active in 1902, so far as sun-spot area is concerned: M. Guillaume's figures showing almost exactly double the area for the north as for the south; 1177 millionths, as against 594. The faculæ were more equally divided; out of 363 groups, 189 appearing north of the equator, and 174 south of it.

Looking back over the cycle just past, it would seem to have been decidedly above the average in length, the middle of the depression with which it began falling about 1889·3, and the middle of that with which it terminated about 1901·8, so that its entire duration was 12·5 years. The period of increase was about 4·3 years and that of decrease 8·2 years, the maximum falling about 1893·6. E. W. M.

The Prominences.—A slight reduction in the mean daily number for the southern hemisphere is shown by the observations made at Kenley during 1902 compared with the previous year.

The figures derived from ninety days of observation in 1901 and eighty-nine days in 1902, are as follows:—

	1901, Per Diem.	1902, Per Diem.
North hemisphere	... 2·56	2·69
South	... 3·06	2·69
Total mean number ...	... 5·62	5·38

The two hemispheres would thus appear to have been reduced to exact equality as regards numbers produced; the southern prominences, however, have exceeded the northern in size, being on the average 6 per cent. larger.

The distribution in latitude has closely followed that in the previous year; thus in each hemisphere there is shown a strongly marked zone of activity, situated roughly between the parallels of 50° and 60°, and two less well-defined and far less active zones in lower latitudes. The limits of the zones of maximum activity are indicated at about 65° north and south, or 5° nearer the poles than was the case in 1901.

A few small and transient eruptions have occasionally been seen in the otherwise barren polar regions.

Speaking generally, the year appears to have been an extremely quiet one. No large eruptive prominences have been recorded, and only one metallic prominence. This was on January 19, in south latitude 30°, and, as so frequently happens, the reversals of the magnesium lines could be traced near the same position in the chromosphere after an entire rotation, viz. on February 15. J. E.

Determination of the Solar Motion.

The last reports of the Council referring to the progress made towards the determination of the direction of motion and velocity of the solar system were in 1891 and 1892, when attention was called to the following researches:

Dr. Stumpe, *Astron. Nach.*, Bd. 156, No. 3000.
Prof. Boss, *Astron. Jour.*, Nos. 195 and 196.
Prof. Porter, *Trans. Obs. Cincinnati*, No. 12.
Prof. Vogel and Dr. Kempf, *Astr. Nach.*, Bd. 132, No. 3150.

During the ten years which have elapsed since these reports a good deal of attention has been given to this subject, both on the theoretical and the practical side. The methods employed have been criticised and elucidated, the available material has been increased by the determination of new proper motions of stars, and the old material has been improved by the more accurate determination of the systematic errors of the catalogues used in the determination of proper motions. In addition the linear velocity of the solar system has been obtained with greatly increased accuracy by new determinations of velocities of stars in the line of sight. Among the many astronomers who have touched on these questions during the last decade the names of Boss, Campbell, Kapteyn, Kobold, Newcomb, Porter, Ristenpart, and L. Struve are specially prominent.

The three best known methods of finding the solar motion are those of Airy, Argelander, and Bessel, to which was added, in 1900, another by Prof. Kapteyn.

(*a*) Airy's method is the most direct and the most simple in practice. The observed proper motions of each star furnish two equations of condition for the parallactic motion of the Sun resolved in three directions at right angles. Each equation involves errors due to observation and also the *motus peculiaris* of the star. If the distances of the stars were known these equations might be solved on two suppositions: (i.) that the irregularities were all due to errors of observation, or (ii.) to the *motus peculiares* of the stars, and the weights adopted in forming the normal equations would be different. As, however, the distances are not known, the equations are solved as they would be were all the stars at the same distance from the Sun.

The other methods adopted all aim at eliminating these unknown distances.

(*b*) In Argelander's method the direction of the solar apex indicated by the stars in a small area of the sky is considered to be the mean of the directions indicated by the individual stars, so that each star thus furnishes one equation.

(*c*) In Kapteyn's method the direction of the solar apex indicated by the motions of the stars in any small area of the

y is considered to be that which makes the sum of the resolved locities in a perpendicular direction zero.

(*d*) Bessel's method consists in determining the poles of the rections of the proper motions of the stars, which would, if e solar motion were the only cause of these proper motions, lie a great circle perpendicular to the direction of the solar tion. The circle is therefore drawn which best collects the rious poles of the observed proper motions.

In the application of these methods different normal nations arise, as is shown by Prof. Kapteyn. He points t that the methods of Airy, Argelander, and Bessel will e better results when the equations of condition are formed m the means of all the stars grouped in small areas than when med singly for each star. When this is done the results found by ry's, Argelander's, and Kapteyn's methods will not differ much. e also does not consider it legitimate to group the stars according their proper motions in the application of Airy's method as ually made, and attributes the regular change found by Stumpe the declination of the apex when proper motions are grouped this manner to an inherent defect in the method. In reply to ticism on his criticism of Airy's method, Prof. Kapteyn makes clear that Airy's method applied to proper motions in *two* rections will lead to the same equations as his own method, d that his criticism of Airy's method is directed only against separate application to right ascensions and declinations.

In this connection Prof. Boss may be quoted, who arrives at e conclusion that the great majority of the stars of the seventh agnitude or brighter will be included between relative distances 0 and 3·0, and under these circumstances the theoretical jections against the very convenient method proposed and illus- ated by Airy practically disappear.

An approximate determination of the solar motion by a atistical method is given by Prof. Newcomb which illustrates e inherent difficulties of the problem in a forcible and extremely structive manner. It is shown how widely the actual dis- ibution of proper motions differs from the normal distribution f the law of errors; and it is pointed out that the best results re to be obtained by diminishing the weights of the more dis- ordant motions. Prof. Newcomb exemplifies his method of ejecting the discordant observations in his discussion of the roper motions of the Bradley stars to give the precession and he solar apex. Out of 3181 stars he rejects 654, or a little more han one fifth.

Dr. Kobold's determinations are on a different footing from he others, as he has used Bessel's method. Applying this nethod to the proper motions of Auwers-Bradley, he found for he declination of the apex of the solar motion $D = -3°$, whereas Airy's and Kapteyn's methods give in different hands values ranging about $D = +30°$. Dr. Kobold obtained a similar result from 523 southern stars taken from Dr. Auwers' Funda-

mental Catalogue, and in a still later paper, in which he use motions of 1709 well-distributed stars, he obtained D = but obtains the more satisfactory result D = + 16″·5, v takes the means for all the stars in the same part of the s does not treat each star separately. The method is c open to the grave objection that a change of 180° in the d of the motion of a star does not affect the result if eacl taken by itself, and it is not easy to separate the dir retrograde motions. According to Mr. Everet Yowell No. 479), who applied Dr. Kobold's method, entirely d results were obtained, according as different appr positions were assumed at the start. The method considered in a brief note by M. Radau (*Bulletin* tom. x. p. 401).

Dr. Ristenpart's determination of the solar motion part of a large paper in which the distribution of the space and value of the precessional constant are also con The stars he uses for precession and solar motion are t the limits of 20° and 25° N. Dec., and the Berlin obser made about 1880 are compared with those of Bessel m Königsberg about fifty years earlier. He uses Airy's r and considers in his equations a possible rotation of th about an axis perpendicular to the plane of the Milky He divides the stars into four classes and obtains result each class.

Class.	Mean p.m.	Mean Mag.	No. of Stars.	M.	A.
	″	m		″	
I.	0·374	7·98	85	·279	286
II.	0·197	8·13	221	·109	275
III.	0·128	8·08	148	·061	255
IV.	...	...	4565	·027	267

where M is the parallactic motion of a star 90° from th and A and D are the R.A. and Dec. of the apex.

Professor Newcomb by the use of Airy's method find the Bradley stars the following results :—

Stars of Small Proper Motion.

Mag.	No. of Stars.	M.	A.
		″	°
1–2·9	64	·659	263·1
3–3·9	135	·561	262·7
4–4·9	327	·347	266·5
5–5·9	731	·314	268·5
6–6·9	1034	·281	277·4
7–	236	·286	278·2

Stars of Larger Proper Motion.

		″	°
All mags.	644	1·67	276·9

s a conclusion from his own and other work to 1899 he A = 18h 30m, D = + 35°, as the most probable position of olar apex.

rofessor Porter's new determination differs from his previous n his adoption of systematic corrections to the catalogues which he derived his proper motions, in the use of ional stars, and in the employment of Kapteyn's method. nds

ss.	Proper Motion.	No. of Stars.	A	D.
	"		h m	°
I.	< 0·2	1037	18 45	54·1
II.	0·2–0·5	1063	18 37	39·6
II.	0·5–1·25	235	18 25	34·4
V.	> 1·25	56	18 13	43·5

rofessor Porter gives little weight to Classes III. and IV., gives a double weight to Class I. on the ground that these are, judging from their mean proper motions, twice as nt as those of Class II., and therefore more widely scattered ace and less likely to be affected by any local drift. As a result from 2000 stars he gives A = 18h 42m, D = 49°·3.

'rofessor Kapteyn included in the same paper a determina- of the solar apex of the value of the precessional constant he corrections required by the proper motions in declination uwers-Bradley. He uses 2640 stars, rejecting the *Hyades Pleiades* groups and the stars observed in one coordinate by Bradley. He also makes a determination from 699 stars rge proper motion taken from Professor Porter's catalogues, ding the stars within 30° of the assumed position of the . He employs three different methods: (i.) statistical, his own explained above, and (iii.) Airy's; and he also ps the stars in several different ways, according to the nitude of the proper motion, the magnitude, and the spectral . He obtains, for the precessional constant and the ctions to the proper motion of Auwers-Bradley, results in agreement with Newcomb.

The results obtained by the several methods are in good ement, the results being

	No.	A.	D.
		h m	′
Bradley Stars ...	2640	18 8	+ 28 4
Porter's Stars ...	699	18 31	+ 32 7

concludes for the most probable position

A = 18h 14m D = + 29°·5

Professor Boss' paper, "Tentative Researches upon Precess- and Solar Motion," contains many valuable remarks on the eral problem. He states as the result of his own studies that best point of attack is offered by the stars brighter than

$7^{m}\cdot0$, after excluding stars having centennial proper motions greater than 10″, and perhaps also stars of magnitudes above the fourth. The determination of the parallactic motion which he gives in this paper is derived from a comparison of the Cape Catalogues for 1850 and 1880. Systematic corrections are applied to the right ascensions according to the conclusions of a paper by Professor Boss in *A. J.* No. 499. The number of stars employed is 3587, extending from the Equator to the South Pole. These are grouped into fifty-seven trapeziums, containing a number of stars varying from 10 to 223. Weights from one to six are assigned to the equations of condition arising from the separate trapezium, so as to allow for the accidental error, the probable amount of the residual systematic error, the effect of star drift, &c. Normal equations are formed separately for the right ascensions and declinations, Airy's method being employed.

The results obtained are : –

	M.	A.	D.
	s	°	°
From Right Ascensions ...	·043	269·3	42·7
,, Declinations	·039	251·4	48·5
,, both	·041	263·7	45·9

As Professor Boss states, the two weak points in this determination are : (i.) the short interval of time between the catalogues, (ii.) it relates only to one hemisphere. To overcome the second objection Professor Boss revises the determination made by Dr. L. Struve by applying corrections to make it agree with Newcomb's system of right ascensions and Boss' system of declinations, and obtains as a result $A = 267^{\circ}\cdot0$, $D = 42^{\circ}\cdot8$. The rest of the paper, as far as it relates to solar motion, is a *résumé* of other investigations, and the most probable position is given as

$$A = 18^{h}\ 20^{m} \qquad D = +\ 45^{\circ}$$

Dr. L. Struve, in view of the differences found by Professor Newcomb and himself in the constant of precession, using the same material re-examined his previous work on the precession and solar motion. Some corrections depending on the right ascensions are applied to the declinations, differences are made in the weighting, and a number of stars excluded. The final result is, however, only slightly altered, being

$$A = 18^{h}\ 20^{m} \qquad D = +\ 23^{\circ}\cdot5$$

The differences in the declination of the solar apex found by L. Struve, Newcomb, and Kapteyn and Boss from the proper motions of Auwers-Bradley are almost entirely caused by the systematic corrections applied to the declinations of Bradley. Struve applied nothing, Newcomb and Kapteyn a correction

. amounted to $-0''.8$ for stars near the Equator, and Boss $-1''.7$.

rofessor Campbell's preliminary determination of the motion solar system is made from the extremely accurate values ie velocities in the line of sight obtained at the Lick vatory. He has observed 280 stars, and deduces

$$V = -20 \text{ kilometres per sec.}$$
$$A = 18^h\ 30^m \quad D = +20°$$

ie determination of the velocity by this method is much accurate than one which can be deduced from the proper ns of stars whose parallaxes are known, and is a result will only be improved by further spectroscopic observations. greement of the position of the apex with that deduced proper motions seems extremely close, especially as there no observations south of Dec. -30, and only few between and $-30°$. Professor Campbell finds for the average ties of the stars in the line of sight a remarkable progres- ith their magnitudes.

No. of Stars.	Mag.	Average Velocity. km.
47	$>3^m.0$	13·05
112	$3^m.1$ to $4^m.0$	16·15
121	$<4^m.0$	19·44

sor Campbell comes to the conclusion that the faint stars oving faster than the bright ones, and remarks that this ndly affects the question of methods of determining the ure of the sidereal universe.

ie following are references to the papers referred to in the report, though a number of shorter papers and notes are found, especially in the *Astronomische Nachrichten.*

... *Ast. Journal*, No. 501 (1901).

bell... *Astroph. Journal*, xiii. p. 80–9 (1901).

yn ... *Proc. Royal Acad. Sciences*, Amsterdam, vol. ii. p. 353 (1900), and vol. iv. p. 221 (1902). *Ast. Nach.* No. 3721 (1901), 3800 (1902). See also *Stein.* A. N. 3779.

ld ... "Nova Acta der Ksl. Leop. Carol.," *Deutschen Akademie der Naturforscher*, Bd. lx. 15, No. 5. Halle (1895). *Ast. Nach.* 3163, 3451, 3591, and others

omb. "The Precessional Constant," *Astronomical Papers of the American Ephemeris*, vol. viii. Part I. (1897). *Ast. Journal*, No. 457 (1899).

npart. *Karlsruhe Observations* (1892).

ruve. *Ast. Nach.*, 3729 (1901), 3816 (1902).

F. W. D.

Investigations of Mr. E. T. Whittaker.

It has certainly been a welcome surprise to mathemat to learn that the famous equation of Laplace admits of a g solution of quite a simple type. This has been shown b Whittaker in the *Monthly Notices*, vol. lxii. p. 617. He proves the following theorem :—

"The general solution of Laplace's equation

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=0$$

is $$V=\int_0^{\pi} f(x\cos v+y\sin v+iz, v)\,dv,$$

where f is an arbitrary function of the two argu $x\cos v+y\sin v+iz$ and v."

From this Mr. Whittaker has shown that the general so of the differential equation of wave motions, namely,

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=k^2\frac{\partial^2 V}{dt^2},$$

can be analysed into simple plane waves.

It is further proved that "distributions of simple waves such that, although each individual wave is periodic with r to the time, yet the total disturbance at any point do vary with the time." As for all such distributions the tot turbance can always be represented by a solution of La equation, we have the most interesting suggestion of an u tory explanation of gravity. The conclusion of Mr. Whitt paper is as follows :—

"This undulatory theory of gravity would require that g should be propagated with a finite velocity, which, however not be the same as that of light, and may be enormously gr

"Of course this investigation does not explain the *ca* gravity ; all that is done is to show that the propagation space of forces which vary as the inverse square of the di does not require for its explanation any other property medium than one which has long been known and accepted

R. S

Nova Persei.

Interest in *Nova Persei* during the year has been n concentrated on the beautiful photographs obtained by Ritchey at the Yerkes Observatory, and by Mr. Perrine a *Lick* Observatory. These photographs, which are given i

Astrophysical Journal, show rings in which there are separate condensations which show large individual motions and in general not radial. The *Astrophysical Journal* and the *Astronomische Nachrichten* contain numerous papers as to the explanation of these phenomena, and, as a result, there seems to be a general consensus in favour of Kapteyn's explanation that finely divided matter having the observed structure is illuminated by light waves emanating from the Nova.

Several attempts have been made to determine the parallax of the Nova. The photographic determinations have resulted in a negative value of the order of $-0''\cdot10$. This is explained by Dr. Bergstrand as due to atmospheric dispersion, and with an allowance for this he obtains the result of $+0''\cdot033$. Dr. Chase, as the result of heliometer measures, has obtained the value $-0''\cdot02$, so that the parallax determinations may be said to confirm Dr. Max Wolf's parallax of $0''\cdot012$, derived on the assumption that the luminosity of the nebula was caused by a wave travelling with the velocity of light. Micrometric measures made by Professor Perrine and Professor Barnard agree with photographic results in showing that the proper motion of the Nova is extremely small. The Nova has diminished about three magnitudes during the year from $7^{m}\cdot0$ to $10^{m}\cdot0$. Isolated observations of the magnitude are to be found in the astronomical journals, but no general discussion has yet been published. A table has been published by Professor Pickering for converting the estimates of magnitude of the neighbouring stars given by Father Hagen to a photometric scale.

Professor Pickering has found a star of the thirteenth or fourteenth magnitude close to the present position of the Nova on a number of plates taken between 1890 October 26 and 1900 March 7, the differences of R.A. and Dec. as obtained from measures made on three of these plates being

$\Delta\alpha$	$-1''\cdot6$	$+1''\cdot2$	$+0''\cdot2$
$\Delta\delta$	$+1''\cdot3$	$-1''\cdot0$	$-1''\cdot2$

It seems probable that this is the coincident with the small star which M. Ceraski found on photographs before the outburst of the Nova. As Professor Barnard points out, now that *Nova Persei* is diminishing in brightness, it will soon be possible to see whether this faint star still exists in the neighbourhood. If not, then it is probable that the Nova is identical with this star. The star found by Professor Pickering was variable to the extent of half a magnitude, and it will be of interest to observe whether the Nova will descend again to the condition of a slightly variable star of between the thirteenth and fourteenth magnitudes.

F. W. D.

Double Stars.

The arrangement of this report is that adopted for some years, the work being referred to under the heads, "Observation" and "Calculation." Abbreviated titles have been used as follows:

M. N.: Monthly Notices, R. A. S.
M. R. A. S.: Memoirs, R. A. S.
A. N.: Astronomische Nachrichten.
A. J.: Astronomical Journal.
A. S. P.: Astronomical Society of the Pacific.
L. O. B.: Lick Observatory Bulletin.
Obs.: The Observatory.
B. A. A.: Publications of the British Astronomical Association.

Observation.—Measures of some stars of special interest will be found:—

Sirius ...	R. G. Aitken, *A. S. P.* 84.
	W. Hussey, *A. S. P.* 84.
δ *Equulei* ...	R. G. Aitken, *A. S. P.* 87.
	W. Hussey, *A. S. P.* 87.
	W. W. Bryant, *M. N.* 1902 March.
	T. Lewis, *M. N.* 1902 March.
ε *Pegasi* ...	T. Lewis, *M. N.* 1902 March.
	W. Bryant, *M. N.* 1902 March.

New Double Stars—

W. J. Hussey. L. O. B. 21. Fifth Catalogue, 100 new doubles, 60 of which are under 1″·0 separation.

W. J. Hussey. A. S. P. 87. Unusual triple star, components of nearly equal magnitude, forming an equilateral triangle (side 1″·5).

Rev. T. E. Espin. A. N. 3784. Seventy-two new doubles.

R. G. Aitken. A. S. P. 82. Principal component of Σ 2[illegible] found to be a close double.

R. G. Aitken. A. S. P. 86. 83 *Aquarii* found to be a close double.

R. G. Aitken. A. N. 3784. Fourth list of new doubles (109).

F. Kaiser. A. N. 3821. 66 new double stars.

Measures of Known Pairs

R. G. Aitken. A. S. P. 86. Measures of the double Aitken 88. Rapid binary.

F. Kaiser. A. N. 3821. Measures of 30 pairs.

R. T. A. Innes. M. N. 1902 April. Cape double star results, 1901.

R. T. A. Innes. *M. N.* 1902 December. Cape double star esults, 1902.

Rev. T. E. Espin. *M. N.* 1902 March. Measures of Σ 484 nd Σ 485.

Rev. T. E. Espin. *M. N.* 1902 May. Micrometer measures double stars with the 17¼-inch reflector.

E. A. Boeger. *A. J.* 522. Measures of 70 pairs, mostly Σ, ade with the 12-inch Washington refractor.

Dr. Jedrzejewicz. *A. N.* 3802. Measures of 25 Struve pairs de in 1887.

John Tebbutt. *M. N.* 1902 April. Micrometer measures of ible stars made at Windsor, N.S.W.

E. E. Barnard. *M. N.* 1902 March. Micrometrical obser-ions of Nova *Cygni*.

H. Thiele. *A. N.* 3837. Measures of 41 pairs by photo-phy, distances ranging from 1″·11 to 10″·99.

Royal Observatory, Greenwich. *M. N.* 1902 March. Results micrometer measures of 400 stars made with the 28-inch ractor in 1901.

W. Doberck. *A. N.* 3798–99. Measures of double stars made Hong Kong in 1901 and part of 1902.

W. H. Maw. *M. R. A. S.* vol. liv. Double star measures ade 1899 to 1901 with 6-inch and 8-inch refractors.

Calculation, &c.—The following papers dealing with calcula-n and general literature have appeared in the course of the ar:

151 ...	R. G. Aitken, *A. S. P.* 86. Orbit, period 27·66 years.
1757, Σ 1785 1837, Σ 1863	T. Lewis, *Obs.* No. 320. Discussion of measures and general notes on.
1883, Σ 1989 2021, Σ 2052 2402, Σ 2434	T. Lewis, *Obs.* No. 321. Discussion of measures and general notes on.
2900, Σ 2944 3041, Σ 3050	T. Lewis, *Obs.* No. 324. Discussion of measures and general notes on.
Orionis ...	F. Comas Solá, *A. N.* 3793. Note on and measures of.
Geminorum	Miss A. M. Clerke, *Obs.* 324.
,,	W. Campbell, *L. O. B.* 20. Variable motion in line of sight.
Herculis ...	W. Campbell, *L. O. B.* 20. Variable motion in line of sight.
,,	P. Lowell, *A. J.* 527, ditto.

W. Hussey. *Obs.* No. 322. "On the measurement of close louble stars."

L. de Ball. *A. N.* 3774. "On the influence of parallax, aberration, P.M., and refraction on the position-angle and distance of two fixed stars."

vin J. Burns. *B. A. A.* Vol. xii. No. 6. "Distribution of
stars in space."
r. Doberck. *A. N.* 3791. "The distribution of Binary
"
. Holmes. *B. A. A.* Vol. xii. No. 7. "Distribution of
ble stars in space."

Variable Stars.

Since the last report the following twenty-three new variable stars have been announced :

Provisional Notation.	R.A.	Decl.	Epoch.	Discoverer.	Reference &c.
	h m	° ′			
97 1901 Velorum	9 24·8	−51 38	1875	Cape	Ann. Report
98 1901 Carinæ	11 14·2	−61 10	1875	"	"
99 1901 Capricorni	20 25·3	−22 7	1875	"	"
1 1902 Cygni	20 50·4	+29 53	1855	Williams	*A. N.* 37
2 1902 Lacertæ	22 41·8	+54 24	1855	Beckhouse	" 3
3 1902 Monocerotis	6 50·6	+ 6 21	1855	Mme. Ceraski	"
4 1902 Geminorum	7 32·6	+20 45	1855	"	"
5 1902 Lyræ	18 56·2	+37 19	1855	Williams	"
6 1902 Draconis	18 5·1	+65 57	1900	Greenwich	*M.*
7 1902 "	18 6·9	+66 9	1900	"	
8 1902 Camelopardi	5 49·4	+74 31	1900	"	
9 1902 Nil	21 55·2	+43 52	1900	Harvard	
10 1902 Cygni	19 7·6	+41 4	1855	Williams	
11 1902 Lyræ	22 5·2	+13 50	1855	Graff	
12 1902 Pegasi	19 10·8	+32 10	1855	Williams	
13 1902 Lyræ	2 30·8	+41 34	1855	"	
14 1902 Persei	20 34·7	+11 21	1855	Anders	
15 1902 Delphini	20 26·0	+16 57	1855	Mme.	
16 1902 "	18 40·8	+43 29	1855	Willi	
17 1902 Lyræ	16 10·3	+38 8	1855	Ande	
18 1902 Coronæ	21 57·8	+34 25	1855		
19 1902 Pegasi	21 0·7	+45 12	1855	Mm	
20 1902 Cygni	20 13·8	+20 39	1855		
21 1902 Sagittæ					

Notes.—Nos. 97. 99. 3. 5. 11. 17. 19. 21.—Lo
Per. 13·4. No. 2.—Independen
Found during the measurem
type variables

large proportion of new *Algol* type variables is noticeable. number of papers containing observations and discussions ble stars which have appeared during 1902 is very large, per or papers having appeared in nearly each number of tronomical publication. We may mention here that the ion of the *Astronomische Gesellschaft*, charged with the ion of a new variable star catalogue, has issued two lists ng the definitive nomenclature and positions of those rtainly recognised as variable since the appearance of r's third catalogue. The first list contains 194 stars, and l in *A. J.* 514; the second list of 24 stars is in *A. J.* 524. sts will also be found in the *A. N.* 3752 and 3809.

usual very complete ephemerides for 1903 of variable ve been issued by Prof. E. Hartwig in part 3 of the *G.* for 1902. These include maxima or minima of the s north of $-23°$ in one table, and south of $-23°$ in both arranged according to R.A. Another table gives and minima arranged according to date. A third part ed to the heliocentric minima of the *Algol*-type stars, final table gives the maxima of the *Antalgol*-type s *Y Lyræ* and *UY Cygni*. Less complete tables, but r many observers' purposes, are published in the *Com-* o the *Observatory*, and in the *Annuaire du Bureau des des.*

fourth report of the Variable Star section of the British mical Association was issued in 1902 June by Colonel arkwick, the director of the section; it is, however, con- observations of Nova *Persei*.

ctober Mr. Packer observed α *Orionis* (*Betelgeuse*) to be than *Capella*. Dr. Copeland circulated the news by an gh telegram. The announcement excited wide interest, ny observations, visual and photographic, have already olished.

A. W. Roberts, of Lovedale, C.C., has a paper on 'Certain rations regarding *Algol*-variation, with special reference D. $-45°$, 4511 in *Proc. Roy. Soc. Edin.* vol. xxiv., In this paper Dr. Roberts develops and applies a of finding the dimensions of *Algol*-systems. A paper by Baxendell on "Pogson's Madras Observations" appeared 520.

ur last report mention was made that Dr. Chandler had ed (*A. J.* 492) that, owing to the pressure of other work, d not be able to issue a fourth edition of his catalogue of stars. The task of preparing a new catalogue has e been taken up by a commission of the *Astronomische haft*, consisting of Messrs. Dunér, Müller, Oudemans, and g. A preliminary report has been published by Prof. er. He remarks that since Chandler's catalogue of some ects was published in 1896 more than 200 new variables en discovered. It is the Commission's wish to issue—

as for the beginning of a new century—as complete a representation of our knowledge of variable stars as possible. It is, therefore, purposed to divide the catalogue into several divisions:—Part I. will contain only certainly determined variables; Part II. is for doubtful objects or those requiring further observation; Part III. will be reserved for variables in star-clusters. It is pointed out that such clusters as *ω Centauri* containing over 100 known variables make such a division very desirable if not absolutely necessary; Part IV. and last is to be reserved for "New Stars" which are hardly to be reckoned as variables. It is also proposed to add to the catalogue a collection of auxiliary tables which will be useful to variable star observers and calculators, such as a table of Julian days and tables for the reduction to heliocentric time of *Algol*-type variables. It is the intention of the Commission to include no star in their catalogue which, if a photographic variable, has not an amplitude of variation of one whole magnitude, whilst for visual observations the minimum range will be half a magnitude. It will only be in quite exceptional circumstances that variables with a smaller range will be admitted. Even so, it is estimated that the new catalogue will contain between 600 and 650 variable stars. In Chandler's catalogues the notes were necessarily exceedingly brief; it is the intention of the Commission to make a radical change in this. They purpose not only giving a short history of each star, but a full description of the form of light-curve and its irregularities if any, as well as a complete index to all the published observations and investigations of period &c. which are of any importance. The Commission are aware of the great increase this will make in their work, but believe it will meet with the approval of astronomers. This index will at once show the practical astronomer the state of our knowledge regarding each star, and thus it will be easy to pick out stars requiring further observation. They specially recommend to young astronomers the observation of such stars as require new observations and offer their advice on the choice of such. The catalogue will be printed in the quarto size of the *Astronomische Gesellschaft* publications. The Commission are now busily engaged on the index and the rediscussion of all the old observations, and hope that in a year's time the conclusion of their task will be in view. They are asking the *Astronomische Gesellschaft* for a grant of 2000 marks in aid of the routine work. R. T. A. I.

Stellar Spectroscopy in 1902.

Spectrum of Nebulæ.—Messrs. Scheiner and Wilsing in their paper in *Ast. Nach.* **159**, 181 (abstract in *Astroph. Jour.* xvi. 234) give the results of their determination, by means of a spectrophotometer, of the relative intensities of the three chief nebular lines at wave-lengths 4861, 4959, and 5007 in nine nebulæ; and

arrive at the conclusions that (1) in the nebulæ examined atio of the brightness of the lines 5007 and 4959 is constant, 2) that of the lines 5007 and 4861 varies considerably (thus rming Keeler's results); (3) the hydrogen (4861) line is ively brighter in the *Orion* nebula than in any of the other læ examined, the intensity ratio of 5007 to 4861 ranging 40 : 1 in *N.G.C.* 6790 to 11 : 1 in the *Orion* nebula; he question of the constancy of the intensity ratio of the lar lines in different parts of the *Orion* nebula has not ved further definite elucidation by the measures made rto. With regard to the last named point it would seem in the light of the first three conclusions of Messrs. iner and Wilsing, constancy in a widely extended nebula l be more difficult of explanation than variation. It is to oped that the authors may be able to deduce from their vations a first approximation to the brightness of, let us the first nebula line 5007 in the various nebulæ which they examined.

contribution to our knowledge of the spectrum of nebulæ s from the Lick Observatory (*Bulletin* No. 19, and *Astroph.* xvi. 52). Mr. Wright has determined the wave-lengths of the brighter nebular lines between 3726 and 5007 from vations of four nebulæ.

pectrum of New Stars.—The following papers have been ished relating to *Nova Persei*:

Lockyer	...	*Proc. R. S.* lxix. 354.
Sidgreaves	...	*M. N. R. A. S.* lxii. 137 and 521.
„	...	*Ast. Nach.* **157**, 197.
Von Gothard	...	„ „ **157**, 141.
Merecki	...	„ „ 158, 43.
Love ...	...	*M. N. R. A. S.* lxii. 524.
Wright	...	„ „ lxii. 630.

lassification of Stellar Spectra.—The interesting address by Professor Schuster to the Royal Philosophical Society lasgow is published in the *Proceedings* of that Society. r the title "The Evolution of Solar Stars" he gives a broad ery suggestive contribution on various points bearing on fication.

he Solar Physics Committee have issued a Catalogue of 470 e brighter stars classified according to their chemistry at olar Physics Observatory, under the direction of Sir Norman ver.

brief summary of the various systems of classification to proposed is given by Professor G. E. Hale in the New ement of the *Encyclopædia Britannica*, vol. 32, under troscopy."

locity in the Line of Sight.—A plan of co-operation between o observatories engaged in spectroscopic determinations of

radial velocity of stars has been inaugurated by the initiation of Professor E. B. Frost, of the Yerkes Observatory, primarily with the view of arriving at definitive values for the velocity of certain selected stars. We may hope that the co-operation, which in the nature of the case is necessarily of an international character, will lead to further developments in a systematic advance in a branch of astronomy which is growing in scope and interest. (*Astroph. Jour.* xvi. 169.)

Mr. Adams gives (*Astroph. Jour.* xv. 214) the velocity of *Sirius* as $-6{\cdot}87$ $^{km}/_{sec}$ at the epoch 1902.06, as determined at the Yerkes Observatory.

Dr. Eberhard (*Ast. Nach.* **157**, 341) has studied the spectrum of the long period variable χ *Cygni* at the Potsdam Observatory, and finds that the shift of the bright lines suggests a velocity of -20 $^{km}/_{sec}$, whilst that of the absorption lines give a velocity of $+2{\cdot}4$ $^{km}/_{sec}$.

Dr. Hartmann (*Sitz. Berlin. Akad.* 1902, p. 237, and *Astroph. Jour.* xv. 287) has by photographic methods determined the radial velocity of three nebulæ whose spectra exhibit bright lines, viz. *G.C.* 4390, *G.C.* 4373, and *N.G.C.* 7027. His results accord well with those of the visual observations made by Keeler in 1890–91.

Dr. Vogel (*Sitz. Berlin. Akad.* 1902, p. 259, and *Astroph. Jour.* xv. 302) has searched for relative motion in different parts of the *Orion* nebula, and finds evidence of its existence. He points out that the differences of velocity found are for the most part smaller than those which Keeler considered detectable in his memorable investigations.

Variable Radial Velocity.—To the list of stars with variable radial velocity several additions have been made in the course of the year :

	α h m	δ ° ′	Period. d	Discovered.	Reference.
ϕ Persei	1 37	+50 11	...	Lick Obs.	Campbell, Lick Obs. *Bull.* 20; *Astroph. Jour.* xvi. 114.
o Persei	3 38	+31 58	4·39	Yerkes Obs.	Adams, *Astroph. Jour.* xv. 214: Vogel, *Sitz. Berl. Akad.* 1902, 1113
ϵ Aurigæ	4 55	+43 40	...	Potsdam	Vogel, *Sitz. Berl. Akad.* 1902, 1068.
η Geminorum	6 9	+22 33	...	Lick Obs.	Campbell, Lick Obs. *Bull.* 20; *Astroph. Jour.* xvi. 114.
δ Libræ	14 56	− 8 8	...	Yerkes Obs.	Adams, *Astroph. Jour.* xv. 214.
ζ Herculis	16 38	+31 47	...	Lick Obs.	Campbell, Lick Obs. *Bull.* 20; *Astroph. Jour.* xvi. 114; Lowell, *Astronomical Jour.* xxii. 190.

	α h m	δ ° ′	Period.	Discovered.	Reference.
ε Equulei	21 11	+ 4 50	...	Lick Obs.	Campbell, *Astroph. Jour.* xvi. 114.
β Cephei	21 27	+70 7	...	Yerkes Obs.	Frost, *Astroph. Jour.* xv. 340.
ι Andromedæ	22 57	+14 47	...	Lick Obs.	Campbell, *Astroph. Jour.* xvi. 114.

Mr. Newall contributes a note (*M. N. R. A. S.* lxii. 124) on the velocity of ε *Persei*.

New Instruments, &c.—A brief popular account, with illustration, of the new Mills reflector and spectrograph is contributed by Professor Campbell to the *Scientific American* for 1902 November 29. An expedition is to be sent from the Lick Observatory with this installation, under the charge of Mr. Wright, to Santiago (latitude 33° S.) for two or three years, and the photographs of spectra obtained in the survey will be sent to the Lick Observatory for measurement and discussion.

It appears, from a contribution to the *Astronomical Journal*, xxii. 190, that spectroscopic work has been begun at the Lowell Observatory.

Professor Scheiner (*Ast. Nach.* **160**, 369) describes a convenient arrangement for giving a comparison line of controllable brightness for measuring faint spectra.

Measurement and Reduction of Observations.—The following contributions have been made to the study of what may be called the right and left personality in measuring photographs of spectra :—

Hartmann, *Ast. Nach.* **155**, 81.
Reese, *Astroph. Jour.* xv. 142, and Lick Obs. *Bull.* No. 15.
Hasselberg, *Astroph. Jour.* xv. 208.

Mr. H. N. Russell (*Astroph. Jour.* xv. 252) has put the analytical method of computing the orbit of a spectroscopic binary into convenient form for taking account of terms of the second and higher order in the eccentricity. Dr. Wilsing (*Ast. Nach.* **134**, 90, 1893) had previously applied the method of developing the observed velocities in trigonometrical series to the investigation of an orbit of small eccentricity, such that terms above the first of the series in e were not required, viz. the orbit of α *Virginis*. Mr. Russell's note indicates how the method may be developed for more general application, not only so far as degree of eccentricity is concerned, but also in cases where observations fail at certain epochs because of peculiarities in the period.

H. F. N.

Star Catalogues.

The Paris Catalogue.—M. Loewy announced to the Academy of Sciences in November last the completion of this catalogue. The observations extend from 1837 to 1881, and comprise 387,474 observations in right ascension and 221,369 observations in declination of 34,733 stars, and have taken M. Gaillot and M. Bossert twenty years to complete. The first volume $0^h - 6^h$ R.A. was published as far back as 1887.

Dr. N. M. Kam's Catalogue.—Some years ago Dr. Kam brought out a catalogue of stars the observations of which had been made in connection with the observations of comets and small planets &c., and had been published in various periodicals, notably in Band 1–66 of the *Astronomische Nachrichten*. This is a second catalogue, on the same lines as the first, based on similar observations published from time to time in Band 67–112 of the *Astronomische Nachrichten*. A great deal of human interest attaches to this volume. Only about a third of it was set up in type when Dr. Kam, after a short illness, died in March 1896; the rest of it has been completed under the direction of Professor H. G. van de Sande Bakhuyzen as a labour of love for his departed friend. The catalogue comprises 6460 stars brought up to the epoch 1875, with annual variation, secular variation, and the value of the third term, and a comparison wherever possible with some catalogue place.

Leiden Catalogue.—This is one of the catalogues brought out under the auspices of the Astronomische Gesellschaft, and consists of 10,239 stars between north declinations 27° 50′ and 35° 10′. The observations were made in the years 1870–1876 and 1880–1898. In the introduction is a discussion of the personal equation of the various observers for magnitudes, and at the end of the catalogue are tables of comparison with Lalande, Bessel, Struve, and Argelander. The publication of this catalogue now leaves only Dorpat to complete the original survey of the northern hemisphere as undertaken by the Astronomische Gesellschaft.

Catalogo di declinazioni medie pel 1900·0 *di* 1419 *stelle comprese nell' emisfero nord, osservate al circolo meridiano negli anni* 1895–99 *di A. Di Legge e F. Giacomelli.*—This catalogue is of declinations only, made at the Royal Observatory at the Campidoglio, and is remarkable for the fact that the places depend in nearly all cases on as many reflexion as direct observations, the results of both positions being given as well as the mean.

Resultate aus Beobachtungen von 560 *Sternen angeführt in den Jahren* 1897–1901 *am grosser Berliner Meridiankreise, nebst Ableitung der Eigenbewegungen von* 233 *Sternen von H. Battermann.*—This paper contains the computations of the proper

motions of 233 stars, and the catalogue places of 560 stars reduced to 1900·0 from observations made at Berlin between 1897–1901 with the meridian instrument. W. G. T.

Latitude Variation.

'A New Annual Term in the Variation of Latitude, Independent of the Components of the Pole's Motion," is the heading of an article in *A. J.* 517, by Prof. Kimura, or, in other words, the Earth's centre of gravity may have an annual periodic oscillation of a few feet in the line of the axis. The basis of this assumption is as follows :—Professor Kimura, noticing that the residuals of the observations of some of the latitude variation stations showed certain periodicities, recalculated the variation of latitude on the assumption that

$$\phi - \phi_0 = \xi + x\cos\lambda + y\sin\lambda,$$

where ξ is variable with respect to time, but at any particular instant has a constant value for all stations. First of all this was done for ten stations between latitude 60° – 21° N. for the period 1899.8—1901.0, secondly from several series of observations in the preceding ten years. The resulting values of ξ for 0·1 of a year from the two discussions are :

Tenths of Year.	ξ (1).	ξ (2).	Tenths of Year.	ξ (1).	ξ (2).
	"	"		"	"
·0	+ ·031	+ ·021	·5	− ·030	− ·033
·1	+ ·023	+ ·020	·6	− ·033	− ·032
·2	+ ·015	+ ·017	·7	− ·031	− ·015
·3	+ ·002	+ ·006	·8	− ·004	− ·012
·4	− ·015	− ·012	·9	+ ·015	+ ·016

The remarkable accordance between these two determinations would seem to establish the reality of a term ξ the mean value of which will approximately correspond to a mean latitude of 42° N. The high precision of these Küstner-Talcott observations, and the enormous mass of them, precludes the idea that this is anything but an objective reality, and emphasises the fact of the great value of this enterprise, and of what can be done by well directed and concerted action. W. G. T.

The Astrographic Chart.

There are few circumstances to specially record in connection with the work of the Astrographic Chart and Catalogue. The first volume of the Catalogue of the zone allotted to the Paris Observatory has been published during the year, containing the

rectangular coordinates, with the necessary plate constants, of 64,264 stars comprised in a zone two degrees broad whose centre is in declination $+24°$. M. Loewy has supplemented this publication by some general remarks on stellar photography and the accuracy of photographic measures which have given rise to a discussion which will be found in the *Monthly Notices*. The four French observatories have continued to make reproductions on paper by heliogravure of the Chart plates on a scale twice that of the original; the numbers of these already published are as follows:—Paris 142, Bordeaux 6, Toulouse 101, Algiers 104. The observatories of Rome and San Fernando are also making enlargements of this kind, and preparations have been made at Greenwich for making similar enlargements by photography.

The state of the work at some of the observatories may be learnt from their annual reports. The third volume of the catalogue of the Potsdam Observatory is in the hands of the printer. The rectangular coordinates of the first volume, which comprises half of the Greenwich zone, is printed but not published. The plates taken at the observatories of the Cape of Good Hope, Sydney, and Melbourne are being measured by means of filar micrometers, and it is believed that the measurement at most of the other observatories is proceeding. H. P. H.

Papers read before the Society from March 1902 to January 1903.

902.

ar. 14. Note on the "green flash." T. W. Backhouse.

The flash spectrum, Sumatra eclipse, 1901. S. A. Mitchell.

Micrometrical and visual observations of Nova *Cygni* (1876) made with the 40-inch refractor of the Yerkes Observatory. E. E. Barnard.

Anomalous occultations of stars by the Moon. G. W. Hough.

The duration of totality at Navalmoral. C. T. Whitmell.

Note on Professor Turner's recent paper on photographic surveying. H. G. Fourcade.

The magnitude of η *Argûs*, 1900–1902. R. T. A. Innes.

On the variation of *S Carinæ*. A. W. Roberts.

Σ 484 and Σ 485, and two pairs. Rev. T. E. Espin.

Double star observations, 1899–1901. W. H. Maw.

New variable stars found during the measurements for the Astrographic Catalogue at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Results of micrometer measures of double stars made with the 28-inch refractor at the Royal Observatory, Greenwich, in the year 1901. Communicated by the Astronomer Royal.

On periodic orbits in the restricted problem of three bodies. E. T. Whittaker.

Mean areas and heliographic latitudes of Sun-spots in the year 1901, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

The parallax and proper motion of Nova *Persei*, from photographs taken at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the images formed by a parabolic mirror. First paper: the geometrical theory. H. C. Plummer.

Apr. 11. Cape double star results, 1901. R. T. A. Innes. Communicated by H.M. Astronomer.

1902.

Apr. 11. Notes on nebulæ observed at the Royal Observatory, Cape of Good Hope, by J. Lunt and R. T. A. Innes. Communicated by H.M. Astronomer.

Tables of $\frac{1}{2}(\theta + \cos\theta)$, with explanation of use. W. S. Aldis.

On stationary meteor radiants: third paper. H. H. Turner.

Results of double star measures with the 8-inch equatorial at Windsor, New South Wales, in 1901. John Tebbutt.

Note on the green flash at sunset. Major E. H. Hills.

Saturn seen through the Cassini division. C. T. Whitmell.

On the probable motion of some of the small stars in the Dumb-bell Nebula. E. E. Barnard.

On the supposed variability of κ *Persei* and 36 *Persei*, and a comparison of the photographic and visual magnitudes of those stars. W. H. Robinson.

On the relative number of star images photographed on different parts of a plate, and on the performance of various object-glasses in this respect. H. H. Turner.

May 9. Jacobi's Nome (q) in astronomical formulæ, with numerical tables. R. T. A. Innes.

Series in the nebular spectrum, and in the bright-line spectrum of Nova *Persei*. E. F. J. Love.

The spectrum of Nova *Persei*, 1901, on and after September 5. Rev. W. Sidgreaves.

Visual and spectroscopic observations of the Sun-spot group of 1901 May 19–June 26. Rev. A. L. Cortie.

Reduction of extra-meridian observations of planets. P. H. Cowell.

Measures of double stars with the 17¼-inch reflector. Rev. T. E. Espin.

On the accuracy of photographic measures. Second note. H. C. Plummer.

June 13. Discovery of Comet Brooks, 1902. W. R. Brooks.

Observations of *Jupiter* made at Mr. E. Crossley's Observatory, Bermerside, Halifax, during the months of July, August, and September 1901. J. Gledhill.

Further observations of the new star in *Perseus*. A. Stanley Williams.

A dark reticle. C. S. Howe.

On the distribution of the stars in the Cape Photographic Durchmusterung. A. M. W. Downing.

Observations of the total eclipse of the Moon, 1902 April 22, at Perth Observatory, Western Australia. W. E. Cooke.

Ephemeris for physical observations of *Mars*, 1902–3. A. C. D. Crommelin.

2.

13. Reductions of photographs of Swift's Comet (*a* 1899) taken at Cambridge Observatory with a portrait lens. L. N. G. Filon.

On the principle of the arithmetic mean. H. C. Plummer.

Observations of Nova *Persei*. T. W. Backhouse.

Comparison of Groombridge's and Struve's right ascensions of close circumpolar stars. W. G. Thackeray.

Experimental reduction of photographs of *Eros* for the determination of the solar parallax. Second paper: Combination of results from Mount Hamilton, Minneapolis and Cambridge. A. R. Hinks.

Further observations of the new star in *Perseus* made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

14. On the mean distance of a planet, as a function of three heliocentric distances and the observed times. Shin Hirayama.

On the general solution of Laplace's equation and the equation of wave motions, and on an undulatory explanation of gravity. E. T. Whittaker.

Observations of Comet Tempel$_2$ (1899 IV.) made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Observations of *Saturn*, 1900 July 17, made at Perth Observatory, Western Australia. Communicated by W. E. Cooke.

Old Cape records of Comets. Communicated by R. T. A. Innes.

On Mr. Love's formula for the wave-lengths of nebular lines. W. H. Wright.

On the place of a star near the variable *RU Herculis*. F. A. Bellamy.

Another form of micrometer for measuring star positions on photographic plates. H. C. Russell.

Observations of the satellite of *Neptune* from photographs taken at the Royal Observatory, Greenwich, from 1902 January 6 to April 10. Communicated by the Astronomer Royal.

Ephemeris for physical observations of the Moon for 1903. A. C. D. Crommelin.

Stereoscopic pictures of Perrine's Comet. Max Wolf.

Sur la précision des mesures photographiques. Réponse à deux notes de M. H. C. Plummer. M. Lœwy.

On the images formed by a parabolic mirror. Second paper: Influence on the measurement and reduction of a photograph. H. C. Plummer.

1902.

Nov. 14. Sir W. Herschel's observed nebulous regions, 52 i number, compared with Isaac Roberts's photograph of the same regions taken simultaneously with th 20-inch reflector and the 5-inch Cooke lens. Isa Roberts.

Newcomb's Fundamental Catalogue : notes and errat W. G. Thackeray.

On a suggestion made by Sir David Gill that th brighter stars are as a whole rotating with respe to the fainter stars as a whole. H. H. Turner.

Note on photographs of Comet *b* 1902 Perrine, taken the Royal Observatory, Greenwich. Communicat by the Astronomer Royal.

Note on a comparison of Groombridge's Catalog (1810) with the Greenwich Second Ten-ye Catalogue (1890), with reference to the questi of an apparent rotation of the brighter stars as whole with respect to the fainter stars. Commun cated by the Astronomer Royal.

Expedition for ascertaining the best location f Observatories. Percival Lowell.

A standard scale for telescopic observations. Perciv Lowell.

Dec. 12. On the accuracy of photographic measures. Thi note : Reply to M. Loewy. H. C. Plummer.

Ephemeris for physical observations of *Jupiter*, 1903- A. C. D. Crommelin.

Cape double star results, 1902, by R. T. A. Inn Communicated by H.M. Astronomer.

On Jacobi's method of facilitating the numerical sol tion of equations arising in the theory of secul perturbations. H. C. Plummer.

Note on binding together réseaux and plates. J. Hardcastle.

Cometary observations made at the Liverpool Obs vatory. W. E. Plummer.

Some developments in terms of the Mean Anoma R. T. A. Innes.

Note relating to the preservation of negatives. F. Bellamy.

Photographic and visual magnitudes of *α Orion* W. H. Robinson.

1903.

Jan. 9. **Preliminary note on the possible existence of t independent stellar systems. F. A. Bellamy a H. H. Turner.**

New double stars detected with the 17¼-inch reflect during the year 1902. Rev. T. E. Espin.

1903.

Jan. 9. On the Sun's stellar magnitude and the parallax of binary stars. J. E. Gore.

A graphical method of applying to photographic measures the terms of the second order in the differential refraction. A. R. Hinks.

Note on plate constants. F. W. Dyson.

Note on the use of Mr. Aldis's Tables of the function $\frac{1}{2}(\theta + \cos\theta)$ in determining the elements of an orbit. H. C. Plummer.

Note on photographs of Comet *d* 1902 Giacobini, taken at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Statistics of stars in a zone of 5° from +65° to +70° Decl., counted on photographs for the Astrographic Chart and Catalogue at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on the reproduction and publication of the photographs for the Astrographic Chart taken at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of occultations of stars by the Moon made at the Royal Observatory, Greenwich, in the year 1902. Communicated by the Astronomer Royal.

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ADDRESS.

Delivered by Professor H. H. Turner, on presenting the Gold Medal of the Society to Professor Hermann Struve.

By the award of the Gold Medal to Professor Hermann Struve for his work upon the satellites of *Saturn* the Council have recognised by the highest means in their power the great value and importance of his contributions to our knowledge of the Saturnian system. It will be seen from the account which I now proceed to give of Professor Struve's researches that they combine in a remarkable manner great observational skill and perseverance with difficult and complicated mathematical analysis and numerical reductions. Professor Struve's earlier observations, which were made with the 15-inch refractor at Pulkowa, were published, together with the investigations derived from them, in a supplement to the Pulkowa observations in 1888.* The later and more elaborate series of observations were made with the 30-inch refractor at Pulkowa: they were published with a very full discussion in a separate volume of the Pulkowa publications in 1898.† These two volumes contain an immense amount of material relating to *Saturn's* system, and also a complete account of the methods by which Professor Struve has himself derived from them so many results of the highest value and interest. During the progress of the work several papers containing the principal results as they were obtained were published in the *Astronomische Nachrichten*.

When Asaph Hall began to observe with the 26-inch refractor at Washington in 1875 the satellites of *Saturn* were some of the first objects which claimed his attention; and in the years 1875, 1876, and 1877 he made a series of observations of the differences of right ascension and declination of the planet and its most distant satellite, *Iapetus*. The mean distance of the satellite determined from such observations depends mainly upon the differences of right ascension; and as this mean distance is the principal factor in determining the mass of the planet, we thus obtain a calculation of this mass, which is practically free from

* Beobachtungen der Saturnstrabanten. Erste Abtheilung. Beobachtungen am 15-zölligen Refractor. Supplément I. aux observations de Poulkova. 1888.

† Beobachtungen der Saturnstrabanten am 30-zölligen Pulkowaer Refractor. Publications de Poulkova. Série II. tom. xi.

the error of the micrometer screw. The value of the mass of *Saturn* so obtained was published by Asaph Hall in the *Monthly Notices* for 1883 November. It is considerably greater than Bessel's value,* derived from observations of *Titan*, and it was the discrepancy between these two determinations which first directed Hermann Struve's attention to the satellites of *Saturn*. The difference was about 6 parts in 1000, and could only arise from systematic errors in one or both of the series of observations; and it occurred to Hermann Struve that the cause of such errors was probably to be found in the difficulty of connecting the satellites with the planet's disc. He decided, therefore, to depart from the usual method of observations, and, in accordance with a suggestion previously made by his father, to measure the distance of one satellite from another. This meant a considerable addition to the labour of reduction, for in each equation he was liable to twelve unknown quantities instead of the usual six which represent the elements of a single orbit; and anyone who has used the method of least squares knows how rapidly the numerical work increases as we add to the number of unknowns. But our Medallist was not one to shrink from labour if he could secure material improvement; and after satisfying himself by a few preliminary experiments § that the method was promising, he set out unhesitatingly on the gigantic task which is now happily accomplished.

He began with the outer and brighter satellites, which were easier to observe. At the two oppositions of 1884–5 and 1885–6 he compared the positions of *Iapetus* and *Titan* on 93 nights, *Titan* and *Rhea* on 72 nights, *Rhea* and *Dione* on 39 nights. Each comparison involved several observations, and gave two equations with 12 unknowns for correcting the elements of the orbit; though, by assuming the orbits of *Rhea* and *Dione* to be sensibly circular, the 12 unknowns were reduced in some cases to 9. The mere statement of these equations involves 25,000 figures, which may give a vague idea of the total amount of work involved in their formation and solution by least squares. The solution was performed twice over—once with all generality and the second time assuming the relation between the mean distances of each pair given by Kepler's Third Law—and the observations of the two oppositions were kept separate. When it was seen from the accordance of the results that there were no outstanding questions to be answered, the solution was repeated, using all the material to the best advantage. Moreover these solutions were not mere pieces of computing, but were watched

* Bessel's value was $\frac{1}{3501{\cdot}6 \pm 0{\cdot}77}$. Asaph Hall's value in the *Monthly Notices*, vol. xliv. p. 7, is $\frac{1}{3482{\cdot}2}$, differing but slightly from his final value $\frac{1}{3481{\cdot}3 \pm 0{\cdot}54}$. ("The orbit of *Iapetus*," Washington, 1885.)

† *Astro. Nachr.* No. 2641–2.

roughout by the keen eye of a man who knew when there was theoretical weakness in the separation of two different elements. truve next determined the perturbations due to the Sun, to the on-spherical shape of *Saturn* and his ring, and to the satellites hemselves ; and thus finally obtained corrected elements of the rbits of these four satellites, *Iapetus*, *Titan*, *Rhea*, and *Dione*, or the epoch 1885.

He then returned to the perturbations just mentioned. To alculate these we must assume values for the masses of the atellites and of the non-spherical portion of *Saturn*, and since ome of the perturbations are cumulative, any error in these assumed values will become manifest with lapse of time. Having now got a set of good elements for 1885, he compared them with old observations from 1787 onwards, and deduced improved values for the secular changes due to the perturbations. Thence it was but a step to determine the mass of *Titan* and the non-spherical portion of *Saturn* with considerable accuracy, the influence of the other satellites compared with these being too small to give good values of their masses. For *Titan* he found the value $\frac{1}{4078}$ of that of *Saturn*. Four years previously Newcomb had deduced the value of $\frac{1}{10000}$ from a beautiful piece of work on the motion of *Hyperion* ; and Tisserand had arrived at a similar result by two independent methods. Mr. Ormond Stone, on the other hand, showed cause why both these determinations should be corrected to about $\frac{1}{1200}$,* so that there was considerable uncertainty in this element when the work of our Medallist appeared. Almost simultaneously with it, however, G. W. Hill† found from *Hyperion* the value $\frac{1}{4714}$, and soon afterwards Mr. Ormond Stone* found numerical errors in each of the other determinations which brought them into satisfactory accordance with those of Struve and Hill, so that order was evolved out of chaos in a sudden and remarkable manner.

In this first memoir there is also a determination of the mass of the spheroidal excess with the ring-system ; but this was revised in the second memoir and may be passed over for the moment. But there is still one very important result of the first series of observations which calls for notice, namely, the determination of the mass of *Saturn*. The mass of any planet compared with that of the Sun follows immediately from the observation of two things : first, the period in which a satellite of the planet revolves round it ; secondly, the mean distance at which it revolves. Now given a sufficient lapse of time there is never any difficulty about the first of these ; by watching a large enough number of revolutions, even rough observations at the beginning and end will give an accurate value of a single period. The real difficulty is with the second factor, the mean distance, or, say for simplicity, the greatest distance at which the

* *Bulletin Astronomique*, tom. v. p. 350.
† *Astronomical Journal*, No. 176.

satellite is seen from its primary. It is humiliating to think that at the present time we cannot measure a distance of 500″ by differential transits within 0″·5, and yet this is actually the case. The values for the mass of *Saturn* found by Bessel and Asaph Hall, quoted at the beginning of this Address, differ by 6 parts in 1000, which corresponds to a difference of 2 parts in 1000 in the distance, or about 1″·0. The work of our Medallist supports Bessel's value on the whole, bringing it rather nearer, however, to that of Asaph Hall; and the latter repeated his observations on *Iapetus* in 1890, with the result of approximating slightly towards Bessel. But the discordance obstinately refuses to be reduced below 0″·5. In his second memoir Struve gives (p. 239) as a final result 1/3495·3; and Asaph Hall's final result is 1/3485·7, leaving half of the original discordance still unexplained. (In 1885–7 Asaph Hall, jun., found the value 1/3501 with the Yale heliometer.) Probably some form of "personal equation" is responsible for the discrepancy. We are familiar, for instance, with errors of transit arising from differences in brightness: if we measured the distance between a bright star and a faint one by observing the interval between their transits, we should not expect to get a correct result without applying a correction for "magnitude-equation," which would be of different sign according as the bright or the faint star came first. If they could alternate in precedence (as a satellite and its primary do), we could get the correct distance from the mean of a pair of observations without knowing or applying the magnitude-equation. For errors of this kind we should naturally be prepared in the case of comparisons, by transit, of a brilliant planet with its satellite; and it is easy to recognise that Asaph Hall's observations at least are affected in this way;* for the residuals systematically change with the relative distance of planet and satellite. But this will not explain distances being observed too small whether the satellite is east or west of the planet. For this one or other of two suppositions must be made: the first is that the second transit is always observed too soon, whether it be of *Saturn* or the satellite. In micrometer work we are familiar with such errors; for instance, in his micrometer observations of the inner satellites Struve found that his measures of distance differed systematically from those of his assistant; and following up the matter he measured the relative distances *ab*, *bc*, *cd* of four stars *a*, *b*, *c*, *d* in a line, and compared their sum with the total distance

* If we take, for instance, the observations in *Astronomical Journal*, No. 253, and group the residuals together for which the difference of transit was greater or less than 30ˢ, we get

over +30ˢ	$v = -0''.24$	over −30ˢ	$v = -0''.37$
under +30ˢ	$v = +0''.21$	under −30ˢ	$v = +0''.18$

The earlier observations in 1875–7 are similarly affected to less degree.

ad, concluding that his own single measures were too small by 0″·088. Even in differential transits cases of the same kind have been found; for instance, in finding the value of a revolution of the screw of a double-image micrometer the screw is turned so that two images of a star are separated by a given interval which is measured by differential transits; and it is generally found that the deduced screw-value varies with the separation, pointing to some systematic error in measuring distances by transits. The error is only large, however, when the two images are very close, and we should scarcely expect to find a sensible error of this kind in the case of objects separated so widely as *Saturn* and *Iapetus*. A second possible supposition is that the difference in brightness of *Iapetus* at Eastern and Western elongation, which amounts to fully two magnitudes, is responsible for the discrepancy. But in either case we must admit that such errors are also likely to affect the relative distance of *Titan* and *Iapetus*, so that the method of Struve would not be *in this case* freer from suspicion than that of Asaph Hall. For the present, while recognising the great merit of Struve's work, we can merely place his result for the mass of *Saturn* alongside of that of Asaph Hall, awaiting further light on this most difficult puzzle, which will perhaps come from further heliometer measures.

Let us now turn to the second series of investigations. The second memoir is nearly three times as long as the first, and probably represents at least three times as much work. Figures are apt to be wearisome, and I must not give too many; but some figures are necessary in order to convey any idea of the marvellous diligence of our Medallist; while to appreciate it properly is no doubt impossible unless one has laboured in the same field. Most of us can understand, however, that considerable labour is necessary for the computation of a single orbit: Struve makes 14 determinations of the orbit of *Rhea*, 14 of *Tethys*, 7 of *Enceladus*, 6 of *Hyperion*, 5 each of *Mimas* and *Dione*, and 2 of *Titan*—53 orbits in all—and this is of course only a fraction of his work. Before it came all the observations, made with his own eyes; after it came an elaborate discussion of the changes in the orbits, leading to results to be presently mentioned.

The observations are certainly beautiful. Taking the system *Tethys-Rhea*, the probable error of a single observation comes out from solutions in seven successive years ±0″·056, ±0″·059, ±0″·059, ±0″·064, ±0″·069, ±0″·069, and ±0″·066. Any other sets might be substituted for these. It is scarcely conceivable that an observer should have a more uniform habit than this, and it is doubtful whether any of the great visual telescopes of the world has ever been, or ever will be, used to better purpose. There are 1300 of these beautiful observations, and the mere statement of the equations for reducing them, which in the last volume ran to 25,000 figures, now requires over 100,000. The total work must have needed millions. Comment is not only

difficult but superfluous; and we will pass to the more noteworthy of the results, especially the unforeseen results, of all this eminently skilled labour.

The first has reference to the position of *Saturn's* equator. Before Struve's work this had been taken to coincide approximately with the plane of the orbits of the satellites, and there was no accurate knowledge of any real differences, which are certainly small. But if the orbit plane of any satellite is inclined to the plane of *Saturn's* equator, it follows from the theory of perturbations that the inclination will remain constant, though the plane will revolve with constant angular velocity, assuming that the spheroidal shape of *Saturn* is the chief perturbing cause. Struve found that he could choose the plane of *Saturn's* equator, so that the orbit of *Tethys* was inclined to it at a constant angle of 65′·1, while its plane revolved with a uniform velocity of 72°·8 per year; and the orbit of *Rhea* was inclined to it at an angle of 20′·5, revolving at a rate of 10°·2 per year. In fact he detected the true position of *Saturn's* equator for the first time, and gave a precision to his result which led him to a discovery of a remarkable kind, as we shall presently see. To follow, however, the course of events, he determined the eccentricities and motions of the apsides of *Enceladus* and *Dione*; and not only a large eccentricity, but a considerable inclination for the orbit of *Mimas*.

Now we have seen that Struve calculated the orbits of all these satellites, not only once, but several times; and he was able to detect, therefore, not only the values at a single epoch of all these eccentricities and inclinations, many of which he discovered for the first time, but the changes in them from epoch to epoch. In this way, as has just been mentioned, he found the rate at which the planes of the orbits of *Tethys* and *Rhea* were revolving on the plane of *Saturn's* equator. He also found—

1. That the Perisaturnium of *Enceladus* is revolving at such a rate that the conjunctions of *Enceladus* and *Dione* always occur in that direction. This actual result was new, but a similar result had been already found by Newcomb in the case of *Titan* and *Hyperion*, and shown to follow from the near commensurability of the mean motions.

2. But in the case of *Mimas* and *Tethys* Struve found a law of perturbation which had not been anticipated even by analogy. The conjunctions of these two satellites oscillate about the direction midway between the *ascending nodes* of these orbits on the plane of Saturn's equator. This is the remarkable discovery above referred to; for it is needless to point out that it could not have been made unless he had first determined the plane of Saturn's equator with great precision. And there were further important consequences. The motion of *Mimas* and *Tethys* had long been a puzzle. Marth had recognised that the mean motion of *Mimas* was variable and had taken refuge in the hypothesis of a secular acceleration, and Dr. Roblin had found, from the dis-

cussion of old observations, that there were changes in the mean motion of *Tethys*. The reason of both these anomalies was now explained by the oscillation or libration of the line of conjunctions, which gave, in fact, a long inequality of seventy years' period and considerable amplitude. Since these curious perturbations have coefficients depending on the masses of the tiny satellites, it was possible to find the masses of *Mimas*, *Tethys*, and *Dione*; and upper limits for those of *Enceladus*, *Rhea*, and *Iapetus*; and it appears that the masses found in this way are smaller than would be expected from the brightnesses compared with that of *Titan* in a ratio which becomes more pronounced as we approach the planet—viz. the masses of *Rhea* and *Dione* are about seven times, *Tethys* thirteen times, and *Mimas* as much as twenty-six times, smaller than the brightness would suggest. Either the density of the inner satellites is much less or their albedo much greater than that of the outer, and this is in accordance with what is known of *Jupiter's* system.

We cannot sufficiently admire the skill with which our Medallist proceeds from one discovery to another, making each secure and complete as he goes, so that it may serve as a sure stepping-stone to the next. From his beautiful observations he calculates a series of orbits, which can only be reconciled by rectifying the plane of *Saturn's* equator; thence he proceeds to the changes of the orbits; and though some of these are quite novel in character, he unravels them with the same ease with which he made the observations. Thence he steps to the masses of the tiny satellites; and finally to an approximate law of physical relationship which may ultimately throw light on the remote history of the Saturnian system. All this with a facility and elegance which make it clear that he is a complete master of all his weapons, from the giant 30-inch telescope to the complexities of gravitation analysis.

And I have by no means completed the list of his achievements. He found also the compression of the body of the planet from the perturbations of the satellites, and his result was in good accordance with the compression derived from measures of its shape. He found that the Ring could not have a mass much greater than that of one of the satellites, which affords a fresh confirmation of the correctness of Clerk-Maxwell's views with regard to the constitution of the Ring. If we were tempted for a moment to wonder whether the story so beautifully unfolded by our Medallist belonged to the regions of romance rather than of solid fact, we should be at once reassured by such independent confirmations as these. It has already been remarked how his value for the mass of *Titan*, which at the time of publication seemed far indeed from any previous suggestion, was almost immediately confirmed from three independent sources. His observations of *Mimas* and *Tethys* elucidated the difficulties found by Marth and Bohlin. His series of values for the masses of the satellites finds an analogue in the system of the planet

Jupiter, and is a new proof of the unity of the solar syste
Two totally independent methods of measuring the ellipticity
Saturn's disc are mutually confirmatory; and finally his val
for the mass of the Ring must be associated with the spectrosco
experiment of Keeler as a beautiful and independent confirmati
of the work of Clerk-Maxwell thirty years before.

We have still to notice a case where Struve not only confirm
the work of others, but added to it in a striking manner. It h
been shown by Newcomb that the conjunctions of *Hyperion* a
Titan were linked in perpetuity with the Aposaturnium
Hyperion. This discovery was, in fact, the prototype of Struv
discovery of a similar relation for the orbits of *Enceladus* a
Dione, and has already been referred to. In such cases it do
not follow that the linkage is absolute; the conjunctions m
librate or swing from side to side of the line of apsides, thou
they never ultimately depart from it; but Newcomb had su
posed that in the case of *Titan* and *Hyperion* there was
sensible libration of this kind. The searching scrutiny of Struv
however, detected a libration of 640 days' period, which may alt
the longitude of *Hyperion* by $\pm 9°$. Let us consider for a mome
what this means in the language of our every-day life. Sail
divide the compass into thirty-two "points," each of which
therefore about eleven degrees. It would be regarded as a sligh
though sensible, alteration in the course of a ship to sail her
single "point nearer the wind," and viewed from a distance th
change, of course, might be difficult to detect. A thousand milli
miles away a tiny satellite is sailing in its orbit with what mig
seem like precise regularity; but the keen vision, optical a
mental, of our Medallist detects that every two years it strs
about a "point" from its expected position, which he considers
vagary so large that it could not possibly be overlooked! Such
the advance which astronomical science has made in the thr
centuries which have elapsed since Galileo first saw that there we
other satellites besides our own Moon.

In the years 1890–1892 the ring of *Saturn* closed up to
thin line of light, and measures were made of the ball and rin
Eclipses of the satellites were also observed at Pulkowa a
elsewhere, and used to determine the dimensions of the ball
an independent method the accuracy of which can be estimat
from the fact that the value of the semi-major axis of the plan
at mean distance found at Pulkowa was $8''{\cdot}720$, and at Princet
$8''{\cdot}716$ (*Monthly Notices*, liv. p. 465). Struve neglects no opp
tunity, as is well exemplified in his treatment of the numbers
old observations of the satellites. To give one instance: So
transit observations of *Iapetus* and *Saturn* were made at M
seilles in 1787, which were published by Lalande and used
him to determine the orbit. But there was obviously somethi
wrong with them. The original records of the observatory bef
1792 had been lost, as Asaph Hall ascertained; and after spe
ing much time in trying to divine some misunderstanding wh

would make sense of them, he gave them up as hopeless. Coming later on the field, Struve might well have been content with the verdict of so able an astronomer as Asaph Hall; but he spared no pains to get at the truth. He selected nine of the best observations for reduction, and from a study of the results concluded that the transits must have been observed across a bar inclined at an angle different from that assumed by Lalande.

By this imperfect sketch I hope to have brought before you in some degree the sterling qualities of the work which we are honouring to-day. I hope to have shown that it is of the first order both in quality and quantity; that our Medallist is not only a skilful observer, and an untiring worker, but in the front rank as a mathematician. For this rare combination of qualities in the man himself, and for what he himself has done alone, he receives this token of our highest esteem.

But it is natural that our thoughts should stray from the present occasion to the past; from the man himself to his father, who was awarded our Medal more than half a century ago; and to *his* father, who received it a quarter of a century before that. For the third time we welcome the name of Struve to our list of honour, and a welcome as cordial awaits an unlimited number of those who in the future may produce work of the same quality as their forefathers. On one fact we dwell with especial pleasure: our hearts warm to think that the venerable figure of Otto Struve has been spared to see the day when his son receives this mark of our esteem. All those who formed our Society when he received our medal in 1850 have passed away; but two of our associates—Otto Struve and Johann Gottfried Galle—remain to tell us that devotion to astronomy enables men to defy the march of years. In a letter dated January 13 Otto Struve regrets that infirmities prevent his undertaking the journey from Karlsruhe to England in order to be present at our meeting, but he begs me to greet the Society cordially from him. Our Medallist himself also finds that he cannot put aside his engagements to be present to-day; and while for our own sake we cannot but regret his absence, we recognise in it another instance of that self-denying devotion to duty without which he could not have carried out so successfully and completely this great work.

The Chairman then, handing the Gold Medal to the Councillor of the German Legation, addressed him in the following terms:—

"Count von Bernstorff, we thank you for being present to-day to receive the Medal on behalf of Dr. Hermann Struve. In transmitting it to him we beg you to assure him that this formal recognition of his work is but the natural outcome of the keen interest and appreciation with which it has been followed by the astronomical world for many years past; and that we are glad to think that its value to him will be enhanced by the knowledge that it ranks him with his venerable father and his famous grandfather."

Note added 1903 *February* 1.—In the "Report of the Counci of the Society to the First Annual General Meeting, 182 February 9," there is the following paragraph (*Mem. R.A.S.* vol. i. p. 25) :—

"The subjects of physical astronomy are so various, and of s mixed and complicated a nature, that the Council defer to a future opportunity their observations on this head. In order however, to show their disposition to encourage the consideratio of such subjects (unhappily too much neglected among th geometers of this country) they recommend the proposal of th Society's gold medal and twenty guineas for the solution of th following prize question :—

"'For the best paper on the theory of the motions an perturbations of the satellites of *Saturn*. The investigatio to be so conducted as to take expressly into consideratio the influence of the rings, and the figure of the planet a modified by the attraction of the rings, on the motions c the satellites ; to furnish formulæ (adapted to the determina tion of the elements of their orbits, and the constan coefficients of their periodical and secular equations) fro observation ; likewise to point out the observations be adapted to lead to a knowledge of such determination. Th papers to be sent to the Society on or before the 1st day February 1823.'"

Apparently no reply was received before the specified date but after the lapse of 80 years the Gold Medal is bestowed for complete solution of the problem proposed at the foundation the Society.

The meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

H. H. Turner, Esq., D.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

Vice-Presidents.

Sir William Abney, K.C.B., R.E., D.C.L., F.R.S.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.
H. F. Newall, Esq., M.A., F.R.S.
E. J. Spitta, Esq.

Treasurer.

W. H. Maw, Esq.

Secretaries.

F. W. Dyson, Esq., M.A., F.R.S.
E. T. Whittaker, Esq., M.A.

Foreign Secretary.

Sir William Huggins, K.C.B., O.M., LL.D., D.C.L., F.R.S.

Council.

Sir R. S. Ball, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.
W. H. M. Christie, Esq., C.B., M.A., D.Sc., F.R.S., Astronomer Royal.
A. A. Common, Esq., LL.D., F.R.S.
Major E. H. Hills, R.E., C.M.G.
A. R. Hinks, Esq., M.A.
E. B. Knobel, Esq.
Thomas Lewis, Esq.
Frank McClean, Esq., M.A., LL.D., F.R.S.
Major P. A. MacMahon, D.Sc., F.R.S.
Captain William Noble.
A. A. Rambaut, Esq., D.Sc., F.R.S., Radcliffe Observer.
W. G. Thackeray, Esq.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXIII. MARCH 13, 1903. No. 5

Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Rafel Patxot Jubert, Passeig Bonanova 64, Barcelona, Spain (proposed by J. Comas Solá) ;

Ole Theodor Olsen, F.L.S., F.R.G.S., 116 St. Andrew's Terrace, Grimsby (proposed by Edward Roberts) ;

Captain Ernest William Owens, Local Marine Board, Dock Street, E. (proposed by Count de Miremont) ; and

Captain B. T. Stevens, 44 Bennett Park, Blackheath, S.E. (proposed by Thomas Lewis).

One hundred and one presents were announced as having been received since the last meeting, including, amongst others :—

M. Karl Bohlin, Sur le développement des perturbations planétaires, presented by the author ; Miss A. M. Clerke, Problems in Astrophysics, presented by the author ; Galileo, Opere, Edizione Nazionale, vol. viii., presented by the Italian

Government; A. Pannekoek, Untersuchungen über den Lichtwechsel Algols, presented by the author; Sydney A. Roberts, Azimuths of the north pole star, latitude 38° to 55° N., for use until the year 1915, presented by the author; Société Belge d'Astronomie, Bulletin, vols. i.–viii., presented by the Society; H. J. Zwiers, Recherches sur l'orbite de la Comète périodique de Holmes, presented by the Leiden Observatory

Drawing of curves of sun-spots and magnetic elements, 1841–96, presented by William Ellis; Drawings of sun-spots, 1850–1865, by J. H. Griesbach, presented by Henry Eichbaum.

Photographs of Comet *Perrine &c.*, presented by V. Nielsen; Photographs of the Moon and Nebulæ taken by G. W. Ritchey with the 40-inch refractor and the 24-inch reflector (lantern slides and transparencies), presented by the Yerkes Observatory.

Letter from Mr. S. C. Chandler proposing the Establishment of a Southern Belt of Latitude Stations.

To the Royal Astronomical Society.

16 *Craigie Street, Cambridge, Mass.*

I beg to submit a statement with regard to a new problem that has arisen above the astronomical horizon within the past year, and to suggest, as a practical means for its possible solution, a proposition which it seems peculiarly fitting that the Society should take into consideration, for reasons that will presently appear

I will limit the present statement of the problem in question to its general features. Its history is very short. In the course of the researches for the establishment by observation of the relative motions of the Earth's axes of figure and rotation, commonly known as the variation of latitudes, there has emerged to view quite unexpectedly an entirely distinct phenomenon. The range of its effect is small, but the evidence of its existence is too definite to permit us to assume that it is not real without the most searching examination. Whether subjective or objective, its origin must be found before we can confidently complete the analysis of the motion of the poles with which it appears entangled in the observations. Its existence is the ingenious discovery of Mr. Kimura, of the International Latitude Station at Mizusawa, Japan, and was announced by him in No. 517 of the *Astron. Journal* (1902 Feb. 14), and in No. 3783 of the *Astron. Nachrichten* (1902 April 5). The only other literature pertaining to it will be found in *A. J.*, 524, and *A. N.*, 3808, and more recently in *A. J.*, 530. All the known facts with regard to it may there be readily examined, so that it is not necessary here to go into particulars. A sufficient description of

is, that it is a small residual phenomenon with a total range 0″·08, independent of the longitude of the meridian in which is observed, but regularly variable with the time of the year, maximum and minimum values being attained about January and July 1. It is too pronounced and regular in its course to ascribed to fortuitous arrangement of residuals. Consequently, ether it arises from some systematic error of observation or m some unknown but real cause, its explanation must be nd.

In the paper last quoted I have endeavoured to examine two estions: first, whether it may be attributed to the effect of llar parallax; secondly, whether it may be due to an annual ration of the Earth's centroid in the line of the terrestrial is. I have shown that the first explanation would lead to at appear, according to our present notions, to be improbable lues of the average parallaxes of the stars employed; and that e second explanation requires a motion in the centroid of an ount that I suppose would be regarded as equally unlikely. I imagine no other cause that will intelligibly account for the erved effect. Unknown anomalies in refraction may be re-nsible, but it is not easy to formulate the action of such an ncy. Finally we have the possibility that the existing eme of observation in the international belt of six stations in itude +39° is defective. Our only resource for further inves-ation of this subject, which I suppose must be attempted ess we propose to stop short in face of the dilemma, is to arge and vary the present programme of operations. In the er mentioned I have suggested the establishment of at least additional belt, to be located in the southern hemisphere; that two observers be provided for each station, so that the ervations, instead of being confined to a few hours of each ht, as in the present belt, shall embrace the whole diurnal arc ween sunset and sunrise. It would be premature here to go the details of arrangement, that being a matter for subse-nt consideration, after it is decided that means for carrying the project can be provided.

Now, the fact to which I desire to direct the attention of the iety is that there already exist observatories in the British onies, namely, at the Cape of Good Hope and at Sydney, S.W., admirably situated to serve as two stations of such a t, so that if a third could be established about thirty miles th of Santiago de Chile, we should have a system extremely ll adapted, both in longitude and latitude, for the purpose of leterminate solution of the coordinates of polar motion by ervation of a common set of stars in the known way; and duplication of the observers and prolongation of the observed s would with much likelihood provide the means for solving new enigma of Kimura's phenomenon. At least there pparently no other resource that presents more chances for its ution.

This system of stations would be :—

	Lat.	Long.	Differences. Lat	Long.
	° ′	°	° ′	°
Sydney ...	−33 52	−151·2		
			0 4	132½
Cape of Good Hope	−33 56	− 18·5		
			0 2	89·2
Santiago (30 m. S.)	−33 54	+ 70·7		

There are other grounds which make the establishment of such a belt in the southern hemisphere desirable. The phases of the annual term of the polar motion occur there in opposite climatic conditions to those in the northern belt.

The fact that two English colonial observatories are so fortunately situated, on the same parallel and in such advantageous difference in longitude, seems to make it appropriate that the Society should deliberately consider this proposition and, if it commends itself to them, lend their influence and encouragement to the undertaking of it under national auspices.

S. C. Chandler.

The foregoing letter was considered at the meeting of the Council of the Royal Astronomical Society (1903 March 13), and the following resolution was passed :—

That the Council of the Royal Astronomical Society is much impressed with the importance of establishing a Southern Belt of Latitude stations for two years at Sydney, the Cape of Good Hope, and near Santiago as proposed by Mr. Chandler, to investigate the subject of Mr. Kimura's term in the latitude variation, and considers it very desirable that this proposal should be carried into effect.

Velocity in the Line of Sight. Selected Stars. Cambridge Observatory, I. 1902. By H. F. Newall.

The present note is a first contribution to the plan of co-operation recently inaugurated under the initiative of Professor E. B. Frost, of the Yerkes Observatory (*Astrophysical Journal*, 1902 October, xvi. 160), and contains (i) a brief statement of the instruments used at Cambridge ; (ii) notes as to the measurement of photographs and the reduction of results ; (iii) a few results relating to the velocity in the line of sight of three out of the ten stars selected for the purposes of co-operative observations as velocity-reference-stars.

If apology is needed for the presentation of such meagre results, it may be offered on the ground that it seems desirable

to publish results for a given year as early as convenient after the end of the year; and though the year 1902 was already well advanced before the plan of co-operation was really inaugurated, there is some advantage in publishing even meagre results at once, in the hope that the collation of the first contributions of the co-operating observatories will lead to the evolution of a form of publication best suited for the purpose in time for the more complete results of 1903.

The following notes summarise a description of the instruments used :—

Instruments :—

Equatorial : Aperture 25 inches (630 mm.), focal length 29 feet (8844 mm.). Used with correcting lens which changes the angular aperture of the convergent beam from $\frac{1}{14}$ to $\frac{1}{10}$, and effectively reduces focal length to 21 feet.

Spectrograph: Slit, reflecting speculum jaws after device of Huggins.

Collimator, aperture $2\frac{1}{2}$ inches (54 mm.), focal length $20\frac{1}{2}$ inches (520 mm.).

Prisms, four, flint, transmitting a 2-inch beam, deviation 180° for H_γ.

Camera, focal length 20 inches (508 mm.).

Temperature control, instrument encased in quilted cover; no electrical heating at present (1903 January).

Measurement of Photographs.—Zeiss Comparator, one revolution of micrometer corresponds effectively to $\frac{1}{10}$ mm. Errors of scale have been carefully determined and are applied in all reductions.

The plates are measured in two positions : (i) red to right (R to *r*), (ii) red to left (R to *l*). In the position "red to right" the scale readings increase with increasing wave-lengths.

The scale of the photographed spectra and the values of a single turn of the micrometer screw are indicated in the following table :—

Wave-length.	Tenthmetres per millimetre.	Velocity $^{km}/_{sec}$ per turn of micrometer.
4200	12·2	87
4250	13·1	92
4300	13·9	97
4350	14·7	101
4400	15·6	106

Reductions.—Wave-lengths of stellar lines are determined with reference to comparison spectrum of Fe spark, by means of Hartmann relation. Hence shift due to velocity &c. is found, $\delta\lambda = \lambda_* - \lambda_\odot$.

Tables and Standards.—Kayser's wave-lengths are used fc comparison lines at present; but as the spark is used, speci determinations will be necessary.

Rowland's tables for the solar spectrum are used for th values of $\lambda\odot$.

Schlesinger's tables for correction for Earth's orbital velocit (Sun's parallax, 8″·80), and a modification of Campbell's tabl for correction for Earth's diurnal motion. Velocity of ligh 300,000 $^{km}/_{sec.}$

Results.—The velocity given for each photograph referred to i the following table is the velocity of the star with reference to th Sun. It is expressed in kilometres per second, and is correcte for the orbital velocity of the Earth and for its diurnal motio and also for the curvature of the spectrum lines, but otherwise the simple arithmetic mean of the values determined for th various lines measured in the spectrum.

Star and No. of Plate.	Date and G.M.T.	Hour Angle.	Slit Width.	Range of Spectrum used.	Comparison Spectrum.	No of * lines.	Velocity reduced to Sun.
α Arietis. 1902	h m	h m	mm	4202 }			km/sec.
F. 346	Sep. 16 12 17	21 51	0·025	4405 }	Fe spark	17	−13·44
F. 353	Sep. 26 11 17	21 34	,,	,,	,,	17	−16·02
F. 374	Nov. 12 10 29	23 54	,,	,,	,,	17	−13·23
			Mean (3 photographs)				−14·26
α Persei. 1902	h m	h m	mm	4250 }			
F. 349	Sep. 19 13 2	21 37	0·025	4326 }	Fe spark	12	−3·14
F. 351	Sep. 24 12 54	21 49	,,	,,	,,	13	−1·89
F. 352	Sep. 25 11 55	20 53	,,	,,	,,	13	−1·83
F. 356	Sep. 30 11 27	20 47	,,	,,	,,	13	−6·24
F. 357	Oct. 2 10 40	20 6	,,			13	−1·48
F. 360	Oct. 15 8 52	19 9	,,			13	−0·57
F. 361	Oct. 15 9 52	20 9	,,			13	−2·32
F. 363	Oct. 18 10 32	21 1	,,			13	−4·72
F. 364	Oct. 22 9 42	20 27	,,			13	−1·22
F. 365	Oct. 22 10 52	21 37	,,			13	−2·96
F. 367	Nov. 8 9 37	21 29	,,			13	−1·86
F. 371	Nov. 12 7 45	19 51	,,			13	−2·68
F. 372	Nov. 12 8 35	20 41	,,			13	−4·37
F. 373	Nov. 12 9 14	21 20	,,			13	−1·31
			Mean (14 photographs)				−2·61 ± 0
			p.e. of single determination				± 1

ind of a.	Date and G.M.T.	Hour Angle.	Slit Width.	Range of Spectrum used.	Comparison Spectrum.	No of * lines.	Velocity reduced to Sun.
otis. 1902		h m	h m	mm	4202 }		km/sec.
134	May 13	13 5	2 17	0·0084	4326 }	Fe spark	13	−4·81
136	June 9	12 40	3 39	,,	,,	,,	14	−5·44
337	June 9	13 50	4 49	,,	,,	,,	14	−7·53
138	June 17	11 0	2 27	,,	,,	,,	14	−4·87
139	June 23	11 10	3 4	,,	,,	,,	7	−5·83
141	July 9	11 11	4 8	,,	,,	,,	13	−6·31
				Mean (6 photographs)				−5·80 ± 0·28
				p.e. of single determination				± 0·68

Accuracy of Measurements.—In order to convey some idea as to the accuracy attained in the measurements, particulars of results of the reduction of plate F. 334 *α Bootis* are here given, with reference to twelve lines that were picked out in the comparison spectra of the iron spark and measured just as if they were to be used as standard lines, and also with reference to seventeen lines measured in the spectrum of the star. This plate was measured by myself * altogether four times, twice in each position of the plate, red to right (R to *r*) and red to left (R to *l*). The measurements of the iron lines and the star lines are dealt with separately, and by the term "completely independent sets of measures" it is intended to convey that (i) the plate was adjusted afresh each time on the micrometer for parallelism both of the spectrum to the slide and of the bisecting wire to comparison lines, and also for focus of the eyepiece, and (ii) the measurements were carried out on different days, so that all question of remembering appearances of individual peculiarities in the photographic images is eliminated.

A. *Comparison lines:*

(1) From two completely independent sets of measures, each R to *r*, differences were taken between the measures on each line.

The mean error of a single difference is $\pm 0^{mm}\cdot 00089$.

Hence the mean error for a single line taken as the mean of two separate measures is $\pm 0^{mm}\cdot 00045$.

Similar results are got from two completely independent sets of measures, each R to *l*.

(2) Next, from two independent sets of complete measures, each being the mean of a measure R to *r* and a measure

* My assistant, Mr. H. J. Bellamy, who has secured all the photographs from which the results recorded in this note have been got, has also measured the plates of α Bootis with results which are in good accord with my own; but I confine myself in the present note to my own measurements for the sake of uniformity, and propose to revert to a comparison of our results in another paper, which is to contain a description of the four-prism spectroscope.

R to *l*, differences were taken between the complete measures on each line.

The mean error of a single difference is $0^{mm}\cdot00079$.

The mean error for a single line taken as the mean of two measures R to *r* and R to *l* is $\pm0^{mm}\cdot00056$.

B. *Star lines:*

(3) From two completely independent sets of measures, each R to *r*,

The mean error for a single line taken as the mean of two measures, each R to *r*, is $\pm0^{mm}\cdot00075$.

(4) From two completely independent sets of measures, each R to *l*,

The mean error for a single line is $\pm0^{mm}\cdot00051$.

(5) From two independent sets of complete measures, each being the mean of a measure R to *r* and a measure R to *l*,

The mean error for a single line taken as the mean of two measures R to *r* and R to *l* is $\pm0^{mm}\cdot00058$.

Taking the extreme values of a turn of the micrometer in the range of spectrum measured as 87 $^{km}/_{sec}$ at the violet end and 99 $^{km}/_{sec}$ at the red end, we find from (2) and (5) that the probable error of a complete measure lies

for a single comparison line between $\pm0\cdot32$ and $\pm0\cdot37$ $^{km}/_{sec}$

and for a single star line between $\pm0\cdot33$ and $\pm0\cdot38$ $^{km}/_{sec}$.

The above results relate simply to settings of the micrometer wire on the lines, and are independent of any question of identification of lines. The peculiarities of what may be called right and left personality are eliminated.

Each of the four sets of measures of F. 334 has been reduced separately, and a velocity has been deduced for each of the 13 star lines used for reduction. Combining them in pairs so as to eliminate right and left personality, we get the probable error of a velocity determined from a single line as $\pm1\cdot3$ $^{km}/_{sec}$ for one pair of measures, and $\pm1\cdot4$ for the other, whilst the probable errors of the final means are $\pm0\cdot36$ and $\pm0\cdot38$ $^{km}/_{sec}$. The value obtained in this way is probably only serviceable as a measure of success in identification of the stellar lines.

If we take the mean velocity for each of the six photographs of *α Bootis* that have been measured, and give equal weight to each as a separate independent observation, we arrive at a more trustworthy value of the probable error of the velocity based on measurements of a single photograph, viz. $\pm0\cdot68$ $^{km}/_{sec}$.

Note on the Spectrum of α Bootis.—In the measurements of the spectra of *α Bootis*, eighteen lines were picked out for measurement in the range of spectrum dealt with, viz. λ 4202—λ 4325. On reduction four of these lines showed peculiarities and were omitted for the purposes of this note. They are evidence either

of peculiar conditions in the star or of the superposition of a second spectrum on the main one. Further measurements and observations have been planned with a view to elucidating the point.

On the Nebula h 2302 N.G.C. 7822 Cassiopeiæ; the Region surrounding H *II. 457 N.G.C. 1665 Eridani, with ten new nebulæ; and* H *III. 558 N.G.C. 7492 Aquarii.* By Isaac Roberts, D.Sc., F.R.S.

The nebula *h* 2302 is described by Sir John Herschel in the *Phil. Trans.* 1833 November, p. 481, as exceedingly faint, of a round figure, diam. 10′±.

Three photographs of the nebula and of the region surrounding it were taken with the 20-inch reflector and exposures of the plates during 90 minutes each, 1901 October 9, 1902 October 25, and 1902 December 2. They show the nebula to be a cloud of very faint nebulosity, irregular in light intensity and structure; the stars DM. 1679, zone 66°, mag. 6·0, DM. 1676, zone 66°, mag. 7·8, and DM. 1675, zone 66°, mag. 9·0, which is the brightest in a cluster of bright and faint stars, are, apparently, involved in the nebulosity. The cloud measures about 42′ of arc from *preceding* to *following* and 38′ from *north* to *south*; there are also faint indications, on the negative, of further extensions of the nebulosity which a longer exposure of the plate would reveal with greater density.

The region around the nebula H II. 457 *Eridani* N.G.C. 1665 includes many nebulæ, amongst which are the following prominent ones:—H II. 457 is shown on the photograph taken with the reflector 1903 February 17, to be a right-hand spiral viewed obliquely, nucleus stellar; these features are not recorded by Herschel.

H III. 589 N.G.C. 1659. The photograph shows this nebula to be a spiral with bright stellar nucleus; very faint star involved in the *north following* end; these features are not recorded by Herschel.

H III. 588 N.G.C. 1643 is described by Herschel as extremely faint; very small; irregularly round; brighter in the middle. The photograph shows it to be bright and pretty large.

h 330 N.G.C. 1656. Sir J. Herschel describes this nebula as extremely faint; irregular figure? The photograph shows it like a large stellar nucleus with extensions of faint nebulosity in *south following* to *north preceding* direction; a faint star near it on the *f.* side.

N.G.C. 1645. D'Arrest describes it as very faint; pretty small; round. The photograph shows it like a pretty bright star surrounded by nebulosity.

N.G.C. 1666 and 1677 Swift V. are on the plate.

N.G.C. 1667 Stephan XIII. is probably a spiral nebula with small irregular nucleus, and large rather dense nebulosity, and not as described in the Catalogue. N.G.C. 1681 Stephan IX. is shown with a bright (not a faint) stellar nucleus surrounded by nebulosity.

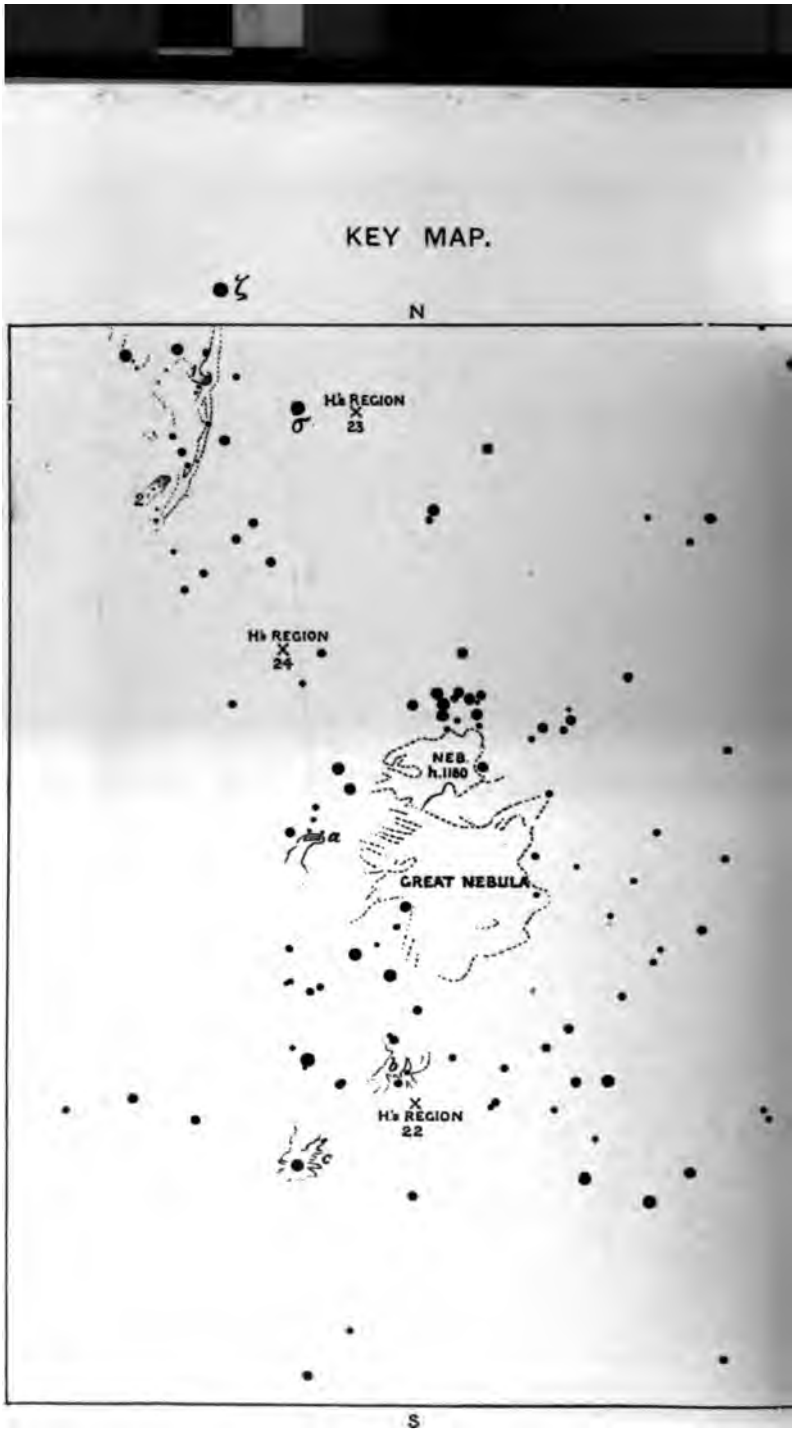
Bigourdan 380 is shown on the photograph as a pretty bright stellar nucleus surrounded by nebulosity elongated in *s.f.* to *n.p.* direction.

The following ten nebulæ are shown on the photographic plate, but are not recorded in Dr. Dreyer's catalogues; they are therefore assumed to be new. The approximate coordinates here given are for the epoch 1860, which is that of the Catalogue.

R.A. h m s	N.P.D. ° ′	
4 39 43	94 56·4	Stellar nucleus surrounded by faint nebulosity.
4 39 53	95 12·7	Small spiral nebula with bright stellar nucleus; indication of star on south end.
4 41 31	95 36·6	Right-hand spiral nebula; faint stellar nucleus.
4 41 51	95 22·9	Probably a spiral nebula; faint and small; elongated in *n.f.* to *s.p.* direction.
4 42 43	95 14·1	Small right-hand spiral nebula; with stellar nucleus; elongated; indications of condensations.
4 43 27	95 19·9	Faint spiral nebula with faint nucleus; elongated in *s.f.* to *n.p.* direction.
4 43 50	95 40·2	Faint spiral nebula, viewed obliquely, with faint stellar nucleus and condensations.
4 43 55	95 8·6	Nebula like small bright stellar nucleus surrounded by nebulosity.
4 44 51	96 28·2	Faint nebula, probably a spiral; brighter in the middle; elongated in *s.f.* to *n.p.* direction.
4 44 58	95 12·7	Very faint nebula with faint nucleus; probably a spiral.

H III. 558 N.G.C. 7492 *Aquarii*, which was photographed with the 20-inch reflector and with an exposure of the plate during 90 minutes, 1902 December 18, is a cluster of very faint stars, described by W. Herschel, in the *Phil. Trans.* 1833, as a nebula eF; vL; 2 or 3′; the faintest thing imaginable.

Besides the nebulæ which have been described above, there are, on this as well as on nearly all of my negatives, such vast numbers of faint stars which are claimed by some astronomers to be nebulæ, that practically the name "Faint Star" might be altogether omitted from astronomical nomenclature. But at present I cannot admit any justification for such a stupendous departure from established usage. The irregular and nebulous appearance of the margins of the stellar images on the photographic plates are, doubtless, caused by atmospheric tremors during the exposures and by instrumental effects.



NEBULOSITIES IN ORION.

NEBULOSITIES IN ORION.

PHOTOGRAPH BY DR. MAX WOLF, HEIDELBERG.

On Three of Sir William Herschel's observed Nebulous Regions in Orion. By Dr. Max Wolf.

Dr. Roberts has recently published in the *Monthly Notices* (vol. lxiii. p. 26) an interesting paper upon Herschel's suspected nebulous regions. Photographing these regions systematically with his 20-inch reflector and 5-inch portrait lens, he has found that nearly all these places show absolutely no nebulosity. This seems to me strange, as both Professor Barnard and myself found the case to be the contrary. I had made contact prints from a photograph of the nebulosities connecting the great θ *Orion* nebula and the ζ *Orion* nebula. My photograph (Plate 11) covers three of Herschel's regions, which Roberts finds free from nebulosity, viz.:

Herschel's No.	R.A. 1900. h m s	Decl. 1900.	Herschel's Description.	Roberts' Description.
22	5 28 53	−6 56	Affected with milky nebulosity.	No nebulosity.
23	5 30 10	−2 43	Affected.	No nebulosity.
24	5 31 56	−4 18	Visible and unequally bright nebulosity. I am pretty sure that this joins to the great nebula in *Orion*.	No nebulosity.

The original plate was taken 1901 January 16 with the a-lens of the Bruce telescope of 16-inch aperture, exposure 6 hours 15 minutes.

Herschel's No. 22: From the great *Orion* nebula in a south-western direction all is filled with whitish nebulosity, connecting the great *Orion* nebula with the neck and head of the great snake which lies round *Orion*, with ζ *Orionis* as centre. This snakelike nebulous wing was first photographed by Barnard and Pickering and afterwards independently by myself, using small portrait lenses. Herschel's No. 22 is in this connecting nebulosity. It is shown on half a dozen or more plates taken since 1891, and it can be seen very well on the plate given here.

Herschel's No. 23 lies east of σ *Orionis*. We see at once that there is bright nebulosity on the plate. We find between ζ and ϵ *Orionis* and the θ *Orion* nebula a beautiful weaving of nebulous masses, with rifts and channels and islands, the two great *Orion* nebulæ appearing only as concentrated clouds in this enormous nebulosity.

Herschel's No. 24 belongs to the same mass and consists of fine nebulous structures.

We find therefore relatively bright nebulæ in these three regions. They are not at all faint or diffuse, but are easily detected by photography, and show a fine network of the same kind as the great *Orion* nebula itself.

At the northern edge of the plate is that remarkable stream of nebulosity running nearly in a straight line southward from *ζ Orionis*. The curious embayment (*a* in the key map) is distinctly visible on the accompanying plate. Dr. Roberts' photograph does not show the whole of the southern part on account of the restricted size of his field. The linear nebulous arm is really curved farther south, going more eastward, and in this stream, in

$$\alpha = 5^h\ 37{\cdot}1^m \qquad \delta = -3^\circ\ 7'\ (1900{\cdot}0)$$

is a second bay (*b* in the key map) similar in form and size to the other.* This bay contains three fine stars free of nebulosity. The eastern neighbourhood shows several curved rifts in the nebulosity. It is impossible here to describe the whole in detail, but I would call attention to three places where the woven nebulosity is exceptionally beautiful:

	R.A. 1900. h	Decl. 1900. ° ′
(*a*)	5 33·6	−5 18
(*b*)	5 31·5	−6 43
(*c*)	5 33·7	−7 9

The concentration (*a*) forms a striking flat ring resembling a smoke ring. The concentration (*b*) is a pretty cloud somewhat similar to the "trifid" nebulæ. Its centre is the B.D. star −6°·1252 of the 9·3 magnitude. The third concentration (*c*), consisting of several bright clouds and dark channels, has much resemblance to the cloud following *ζ Orionis*. The fainter parts embrace the 5th magnitude star B.D. −7°·1152 = *d Orionis*.

Königstuhl-Heidelberg Astrophysical Observatory:
1903 *February*

On the Period and Light Curve of (7514) *UY Cygni.*

R.A. = 20h 52m 16s, *Decl.* = + 30° 2′·8 (1900).

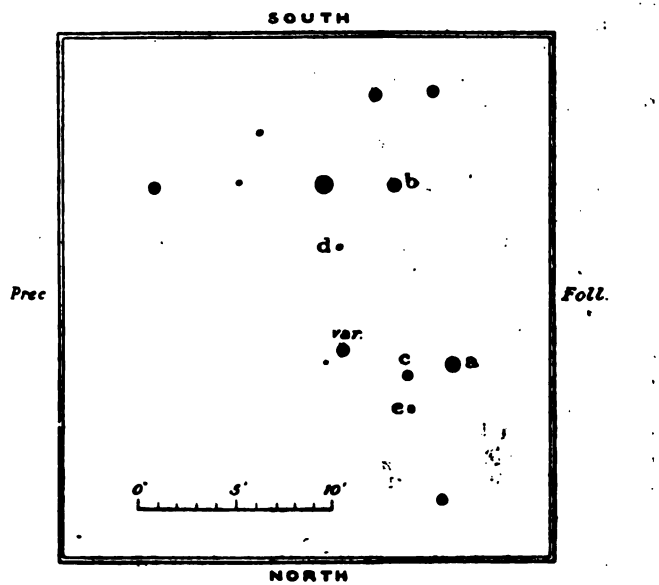
By A. Stanley Williams.

The observations on which the following results are based number altogether 238, and consist of 12 photographic observations from plates taken with a 4·4-inch portrait lens, 41 visual observations made with a 2¾-inch refractor, and 185 made with a 6½-inch reflector. But 15 of these 238 observations were rejected owing to their having been marked as uncertain, or as

* For the history of this nebula see the note by Miss Clerke to my article in the *Journal Br. Astr. Assoc.* 1890, p. 252.

bly affected by cloud or fog;* two on account of the time having been recorded; and six for discordance. One observation in addition was accidentally omitted, so that the actual ber made use of is 214.

Most of the observations were made with the 6½-inch ctor and a power of 73, and these have been considered as hard, and the other observations have been reduced so as to orm to them. It had at first been intended to use the ctor observations alone, at any rate for the purpose of constructing the light curve, but the others on reduction agreed so with these on the whole, that they likewise have been loyed. A few of the refractor observations were, however, n half weight.



The observations were generally made in the form of short iences of steps, the sequence commencing usually with the parison star *a* and ending with *d* or *e*. A light scale having i formed from about 50 such sequences observed with the ctor, all the observations, including those made with the ictor and the photographic observations, were as far as ible reduced to this scale.† The photographic observations

* Cloud and fog were abnormally prevalent in 1902, adding much to the ulty of satisfactorily observing very rapid variables.

† The value of a step varies somewhat from night to night as regards the group of stars, and even on the same night in the case of different rs. This is in conformity with the statement by Professor H. C. Wilson,

were reduced on the assumption that the photographic light changes are the same as the visual; an assumption which would not be correct if, for instance, the star underwent any decided change of colour in the course of its variations in brightness. As, however, the photographic observations when thus reduced agree satisfactorily with the visual ones, it is evident that the photographic variation is substantially the same as the visual, so far as regards this particular star. In making the visual observations the head was always so held that a line through the eyes was parallel to a line joining the two stars compared, in order to eliminate the effects of "position error."

The comparison stars used will readily be identified by means of the preceding little diagram, in which the brightest star shown is B.D.+29°.4240 (8·3 mag.). The brightness of each comparison star according to the adopted light scale is given below, together with the corresponding magnitude on the assumption that the magnitude of the star *c* is 10·20, and that the value of a step is 0·05 magnitude.

Comparison Stars.

Star.	Scale.	Magnitude.	Star.	Scale.	Magnitude.
a	36·4	8·81	*d*	0·2	10·62
b	26·1	9·33	*e*	0·0	10·63
c	8·6	10·20			

Owing to the unfavourable weather the number of completely observed maxima is not so large as had been desired, and in order to secure the best results it was found necessary to make use of a mean light curve. This provisional light curve was constructed in the following manner. The observations of the different maxima having been independently charted upon *transparent* squared paper, the results were superimposed one upon the other, and adjusted so as to correspond as closely as possible to what seemed to be the mean result. The superimposed sheets of squared paper were then held up to a bright light, and the mean curve carefully drawn. This resulting provisional light curve, it may be mentioned, is almost identical with the final light curve based upon all the observations, and reproduced in Plate 12. The exact times of maximum were then derived with the help of this provisional light curve from the separate observations of each night. The observed times of maximum are given in Table I. below. The weights in the last column were assigned at the time when the different maxima were determined.

when discussing the numerous observations of Nova *Persei*, to the effect that the value of a step was for most of the observers a variable quantity (*Popular Astronomy*, vol. ix. p. 481). In the case of the present star the observations were in most cases reduced so as to make the step value correspond to the mean, or standard, step value of the adopted scale.

TABLE I.

Observed Maxima.

Ep.	Date.	Geoc. G.M.T.	Red. to ⊙	Helioc. G.M.T.	O−C.	Wt.
	1900.	h m	m	h m	m	
0	Nov. 22	10 55	−0·4	10 54·6	− 1·0	1
	1902.					
729	Jan. 5	5 43	−4·8	[5 38·2]	[+86·3]	½
1038	June 27	11 22	+3·8	[11 25·8]	[+83·4]	...
1040	„ 28	12 28	+3·8	[12 31·8]	[−25·2]	...
1063	July 11	11 5	+5·1	[11 10·1]	[+44·2]	¼
1072	„ 16	11 40	+5·5	11 45·5	+13·2	¾
1138	Aug. 22	11 29	+6·5	11 35·5	− 1·6	¾
1145	„ 26	9 32	+6·5	9 38·5	−10·1	1
1147	„ 27	12 29	+6·5	12 35·5	− 7·6	1
1186	Sept. 18	9 34	+5·8	9 39·8	+ 9·9	1
1293	Nov. 17	9 13	+0·3	9 13·3	− 2·7	1

The first maximum, it should be mentioned, is photographic. e variable appears distinctly brighter upon this photograph an it does upon any of the others, and for this and other sons it seems pretty certain that the star was either at, or at y rate very near, its maximum brightness at the time; whilst long interval by which this observation precedes the others ders it of special value for determining the period of varia-n. The plate in question was exposed for one hour, from ^{h} 25^{m} to 11^{h} 25^{m}, on 1900 November 22; and a note states t the sky was rather hazy, particularly towards the end, when altitude was lower. Under ordinary circumstances the ximum brightness of the variable would no doubt occur before middle of the exposure, owing to the increase being more id than the decrease. But in the present case the greater iness towards the end would tend to equalise matters, and middle of the exposure has consequently been assumed as actual time of maximum. The third and fourth maxima re observed by Dr. Hartwig at the Bamberg Observatory.* e bracketed maxima were not used in determining the period variation.

From the data contained in the foregoing table the concluded ments of maximum are:—

ximum = 1902 August 22, 11^{h} 37^{m}·1 G.M.T. + 13^{h} 27^{m} 2^{s}·85 E.†

* See *Vierteljahrs. der Astron. Gesells.*, Jahrgang 37, Heft 3, p. 284.

† This period is 61^{s}·26 longer than that published by the writer in the *N.* 3771, and it would seem that in connecting the observations of the mn-winter of 1901–02 with those of the previous year one period too ay must have been assumed. This would account for the disagreement ween the predicted and the observed times mentioned by Hartwig *. cit.*).

and the residuals according to these elements will be four the penultimate column of Table I. With reference to thes may be mentioned that the maximum No. 2 is based only observations made a considerable time after maximum, an fact it rests practically upon a single observation ; whilst or the two untimed observations, previously referred to, follows one and shows that the star was probably estimated too brigh the first observation. The details of the two maxima observe Hartwig are not at present known to me. In the cas maximum 5 the observations (five in number) are discordant *se*, and these five observations have consequently been reje altogether, and they are included in the list of six observat rejected for discordance as already mentioned.

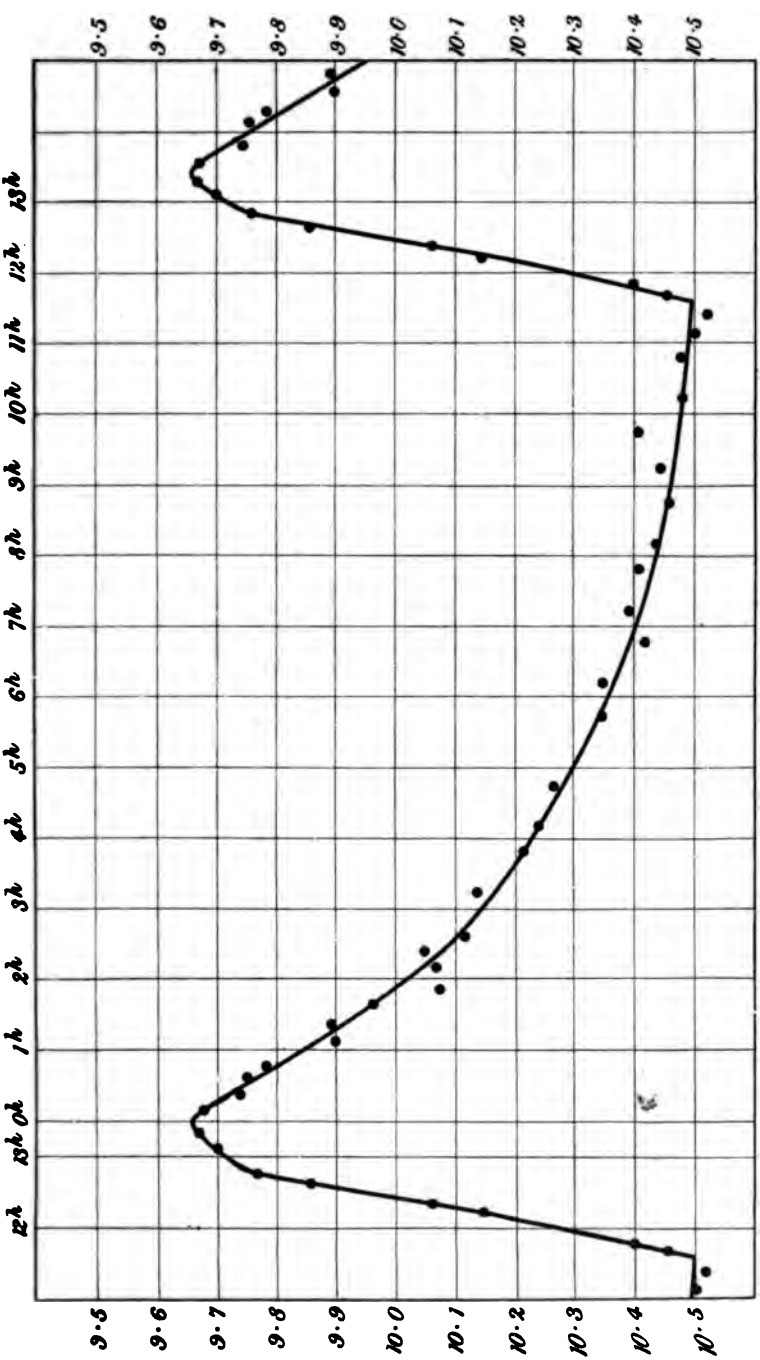
Owing to the great rapidity with which the rise f minimum to maximum takes place, the time when the vari attains to equality with the comparison star *c* can be obse with great exactness ; in fact with greater accuracy than the actual maximum. This time is denoted by T_o, and Table contains the observed times of T_o and other data correspon to Table I. It will be seen that the residuals are here small ; so that similar observations in future years sh enable the period to be ascertained with great exactness.

TABLE II.

Observed Times of T_o.

No.	Ep.	Date 1902	Geoc. G.M.T. h m	Red. to ⊙ m	Helioc. G.M.T. h m	O−C m
1	1138	Aug. 22	10 10	+6·5	10 16·5	− 0·1
2	1145	„ 26	8 23	+6·5	8 29·5	+ 1·4
3	1147	„ 27	11 18	+6·5	11 24·5	+ 1·9
4	1186	Sept. 18	8 27	+5·8	[8 32·8]	[+23·5]
5	1293	Nov. 17	7 52	+0·3	7 52·3	− 3·2

The mean light curve has been derived by arranging all observations in order of the interval by which they follow last preceding maximum, and then forming them into gro and taking the means. For about two hours before and a maximum the observations have been formed into 15-mi groups, and for the remainder of the period into half-ho groups, with the exception of one group, which is an hourly The reduction to the Sun has been effected for all observat made when the star's brightness was changing rapidly. resulting mean values were then plotted upon squared pape a large scale, and a smooth curve drawn carefully through dots representing the mean results. This final mean curve is given on a smaller scale in Plate 12. The data which it is based are contained in Table III. Column 4 of table gives the magnitude from the mean light curve, de



LIGHT CURVE OF UY CYGNI.

from the large scale diagram referred to above; and column 5 the difference between the observed brightness and the brightness according to the curve. The mean difference, without regard to sign, is 0·019 magnitude; whilst the largest difference only amounts to 0·07 magnitude.

TABLE III.

Grouped Observations.

No.	Interval from prec. maximum h	m	Observed Magnitude	Magnitude from curve	O−C Mag.	No. of Obs.
1	0	8	9·67	9·68	−0·01	7
2	0	26	9·73	9·73	·00	5
3	0	39	9·75	9·77	− ·02	5
4	0	50	9·78	9·80	− ·02	3
5	1	7	9·90	9·87	+ ·03	7
6	1	23	9·89	9·92	− ·03	5
7	1	39	9·96	9·96	·00	7
8	1	51	10·07	10·00	+ ·07	6
9	2	8	10·06	10·04	+ ·02	8
10	2	22	10·04	10·08	− ·04	4
11	2	42	10·12	10·12	·00	6
12	3	15	10·13	10·17	− ·04	5
13	3	49	10·22	10·22	·00	8
14	4	14	10·25	10·24	+ ·01	7
15	4	44	10·27	10·28	− ·01	6
16	5	40	10·34	10·33	+ ·01	9
17	6	14	10·34	10·36	− ·02	6
18	6	47	10·42	10·39	+ ·03	4
19	7	15	10·39	10·41	− ·02	8
20	7	47	10·41	10·43	− ·02	5
21	8	13	10·43	10·44	− ·01	10
22	8	49	10·46	10·45	+ ·01	3
23	9	15	10·43	10·46	− ·03	7
24	9	43	10·41	10·47	− ·06	9
25	10	14	10·48	10·48	·00	6
26	10	45	10·48	10·49	− ·01	4
27	11	7	10·50	10·49	+ ·01	10
28	11	26	10·52	10·49	+ ·03	5
29	11	38	10·46	10·46	·00	6
30	11	51	10·40	10·33	+ ·07	5
31	12	11	10·14	10·14	·00	5

No.	Interval from prec. maximum. h m	Observed Magnitude.	Magnitude from curve.	O−C Mag.	No. of Obs.
32	12 22	10·06	10·04	+ ·02	4
33	12 37	9·85	9·89	− ·04	4
34	12 53	9·76	9·76	·00	5
35	13 8	9·70	9·70	·00	4
36	13 23	9·67	9·67	·00	6

It will be seen that the light curve is a somewhat peculiar one, being remarkable for the very rapid rise from minimum to maximum. The decline too is very quick at first, becoming gradually slower and slower, whilst the star remains with but little change near minimum brightness during nearly half its period. The curve is thus almost a facsimile of that of *Y Lyræ*.* Amongst isolated stars there seems to be only one other possessed of quite this extreme form of light curve and having a period of about half a day. This is *S Aræ*. The following is the description given by Dr. A. W. Roberts of the light changes undergone by this latter star. 'The remarkable feature about this star is its rapid rise to maximum. In $1^h\ 10^m$ it passes from its minimum to its maximum phase. The rate of increase is $0^m{\cdot}1$ every five minutes. After maximum passage the rate of variation steadily slows down till some three hours before minimum it is almost stationary.'† This description would apply equally well to either *UY Cygni* or *Y Lyræ*, with some little modifications arising from the slightly longer periods of these two stars. The resemblance is brought out very strikingly if the following elements of the three stars are placed parallel to each other.

	Y Lyræ	UY Cygni	S Aræ
Period	$12^h\ 3^m\ 52^s$	$13^h\ 27^m\ 21^s$	$10^h\ 50^m\ 47^s$
Duration of rise	$1^h\ 40^m$	$1^h\ 53^m$	$1^h\ 10^m$
Ratio increase to decrease	0·16	0·16	0·11
Range of variation ...	mag. 1·03	mag. 0·84	mag. 1·2

It is to this extreme type of variation combined with a period approximating to half a day that Professor S. I. Bailey seems to have applied the name of 'Cluster Type.'‡ But as regards the general *form* or characteristics of the light curve there would seem to be no essential difference between the above-mentioned three stars, or the stars of the so-called Cluster type, and the stars of the ordinary short period type, like *δ Cephei*, *T*

* See *Monthly Notices*, vol. lxii. p. 206.

† *Astronomical Journal*, xxi. 91.

‡ *Astrophysical Journal*, x. 258. Dr Hartwig has used the term 'Antalgol-type' to designate the extreme type of variation exhibited by *Y Lyræ* and *UY Cygni*.

Vulpeculæ, and others. The only material difference is that in the case of the average short period variable the ratio of the increase to the decrease averages about 0·34, as compared with 0·14, the average ratio in the case of the above-mentioned three stars, and that the period is also usually much longer. There is, however, no distinct line of demarcation between the two classes, and variables are to be met with in almost all the intermediate stages. Thus, the ratio of increase to decrease is 0·22 in the case of *V Velorum*; 0·23 in the case of *RV Scorpii*; 0·24 in the case of *U Triang. Austr.*; 0·27 for *V Centauri*; 0·29 for *T Monocerotis*; the same for *R Muscæ*; 0·30 for *δ Cephei*; 0·31 for *T Vulpeculæ* and *Y Sagittarii*. Also this ratio is 0·14 in the case of *U Carinæ*, although the period of this star is as long as 38·7 days. The mean ratio for 36 short period variables (not including *U Carinæ*, *S Aræ*, *Y Lyræ* and *UY Cygni*) is 0·34.* It appears, therefore, that the so-called 'Cluster type' is really only an extreme form of the ordinary short period type.† Nevertheless, as it is convenient to have some suitable term to designate this extreme type of short period variation, it seems desirable to retain the name of Cluster-type, unless that of Antalgol-type should be preferred.

It has already been mentioned that six observations were rejected for discordance. Five of these, near the maximum of 1902 June 11, were rejected on account of their being discordant *inter se*. The remaining case of discordance is somewhat peculiar. The observation was made on 1901 December 19, with the 2¾-inch refractor at $1^h\ 4^m$ before the computed time of maximum, and according to this observation the star had already attained to nearly its full brightness. The cause of this may possibly be that this maximum occurred, or the rise set in, a little earlier than usual; particularly since, as in the case of *Y Lyræ*,‡ there is some evidence to show that the maxima are not all quite alike, some being more accentuated than others. It is difficult, however, to decide how far such differences may not be due to subjective causes; and in the case of an isolated observation it is impossible to be certain of the absence of fog or cloud, even though none was noticed at the time.

Table IV. contains the full elements of the variable, and Table V. the computed heliocentric Greenwich mean times of every tenth maximum during the remainder of the present year.

* These ratios have been derived from the data contained in Dr. Chandler's Third Catalogue of Variable Stars, and in Roberts' Catalogue of Southern Variable Stars in the *Astronomical Journal*, Nos. 491–492.

† I am indebted to Mr. P. S. Yendell, of Dorchester, Mass., U.S.A., for kindly drawing my attention to the similarity in the forms of the light curves of the 'Cluster type' and ordinary short period type of variation. Roberts has already remarked this in the case of *S Arae*.

‡ See *Monthly Notices*, lxii. 204.

TABLE IV.

Elements of UY Cygni.

Period of variation ...	...	day 0·560658 =	h m s 13 27 20·85
Epoch of T_0	...	1902 Aug. 22, = J.D. 2415984·4282	10 16·6 G.M.
Epoch of maximum ...	...	1902 Aug. 22, = J.D. 2415984·4841	11 37·1 "
Maximum brightness...	...	9·66 mag.	
Minimum brightness ...	...	10·50 mag.	
Minimum to maximum	..	$1^h\ 53^m$	
Maximum to minimum	...	$11^h\ 34^m$	
Ratio increase to decrease	...	0·16	

TABLE V.

Computed Times of Maximum.

Ep.	Date. 1903.	G.M.T. h m	Ep.	Date. 1903.	G.M.T. h m
1548	April 9	8 30	1788	Aug. 21	21 53
1558	14	23 3	1798	27	12 26
1568	20	13 37	1808	Sept. 2	3 0
1578	26	4 10	1818	7	17 33
1588	May 1	18 43	1828	13	8 7
1598	7	9 17	1838	18	22 40
1608	12	23 50	1848	24	13 14
1618	18	14 24	1858	30	3 47
1628	24	4 57	1868	Oct. 5	18 21
1638	29	19 31	1878	11	8 54
1648	June 4	10 4	1888	16	23 28
1658	10	0 38	1898	22	14 1
1668	15	15 11	1908	28	4 35
1678	21	5 45	1918	Nov. 2	19 8
1688	26	20 18	1928	8	9 42
1698	July 2	10 52	1938	14	0 15
1708	8	1 25	1948	19	14 49
1718	13	15 59	1958	25	5 22
1728	19	6 32	1968	30	19 55
1738	24	21 6	1978	Dec. 6	10 29
1748	30	11 39	1988	12	1 2
1758	Aug. 5	2 13	1998	17	15 36
1768	10	16 46	2008	23	6 9
1778	16	7 19	2018	28	20 43

Multiples of the Period.

	d	h	m		d	h	m
1p =	0	13	27·3	6p =	3	8	44·1
2 =	1	2	54·7	7 =	3	22	11·4
3 =	1	16	22·0	8 =	4	11	38·8
4 =	2	5	49·4	9 =	5	1	6·1
5 =	2	19	16·7	10 =	5	14	33·5

How: 1903 March 4.

Observations of Comet b 1902 (*Perrine*), *from Photographs taken at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The following table of Right Ascensions and Declinations of Comet *b* 1902 are, with the exception of those on September 6, 12, and 13, obtained from photographs with the 30-inch reflector. That on September 6 was taken with the astrographic equatorial, and those on September 12 and 13 with the 26-inch refractor. Owing to the rapid motion of the comet it was desirable to obtain photographs with shorter exposures than these instruments required, and accordingly from September 16 the reflector was used.

The number of exposures on each plate was in most cases four. The four images of the comet were measured in direct and reversed positions of the plate by Mr. Davidson and Mr. Melotte. Eight reference stars were measured, two of the images being measured direct and reversed by Mr. Davidson, and the other two by Mr. Melotte.

The catalogues of the *Astronomische Gesellschaft* were used for the positions of the reference stars, which were usually chosen so that their mean position should be near the centre of the plate. The stars were generally chosen between the limits 6 and 22 of the réseau, *i.e.* within 40′ from the central réseau lines, which are numbered 14.

The right ascensions and declinations of the comet given in the table are corrected for the part of the aberration which arises from the motion of the Earth, but not for the part arising from the movement of the comet itself. The corrections for parallax have not been applied.

Right Ascensions and Declinations of Comet b 1902 (*Perrine*), *from 1*
taken with the 30-inch Reflector and the 26-inch Refractor of th
Equatorial and with the Astrographic Equatorial.

Date. 1902.				R.A. 1902·0.			Decl. 1902·0.			Parallax R.A. Log. Factor.	Parallax R.A. Corr.	Lo
	h	m	s	h	m	s	°	′	″		s	
Sept. 6	13	29	30	3	11	35·88	+37	2	49·6	9·4765	−0·27	
12	11	36	27	2	59	18·09	40	25	48·0	9·6197	0·45	
13	10	53	45	2	56	25·23	41	5	30·7	9·6584	0·51	
16	8	50	18	2	45	35·70	43	18	27·9	9·7032	0·64	
16	9	29	9	2	45	28·54	43	19	48·4	9·7023	0·64	
17	9	35	33	2	40	47·28	44	10	59·3	9·7045	0·67	
18	8	37	5	2	35	44·19	45	2	31·4	9·7162	0·71	
18	9	16	58	2	35	34·93	45	4	5·0	9·7137	0·71	
19	9	59	2	2	29	25·37	46	2	33·5	9·6968	0·71	
20	9	31	33	2	22	44·48	47	1	15·3	9·7151	0·77	
21	8	45	56	2	15	14·28	48	1	57·3	9·7368	0·85	
22	9	20	27	2	6	7·98	49	8	59·7	9·7246	0·86	
25	7	38	0	1	31	21·36	52	31	8·0	9·7799	0·89	
26	9	9	2	1	14	30·58	53	44	7·5	9·7934	1·21	
27	11	31	29	0	54	4·10	54	54	51·2	9·2122	0·33	
28	10	41	56	0	33	15·75	55	49	10·3	9·3755	0·51	
29	6	59	14	0	12	43·35	56	27	8·8	9·7984	1·40	
Oct. 2	8	42	7	22	41	40·26	56	31	27·8	9·3425	−0·55	
8	7	9	47	19	54	42·23	42	24	22·5	8·6592	+0·12	
10	10	31	37	19	17	20·40	34	46	49·3	9·6160	+1·05	
12	6	57	44	18	53	4·64	28	24	54·7	9·1811	+0·36	
14	6	31	45	18	33	4·97	22	15	14·8	9·1682	0·33	
15	8	54	50	18	23	59·19	19	11	7·6	9·5327	0·72	
16	6	40	20	18	17	20·70	16	50	45·3	9·2840	0·39	
17	8	48	32	18	10	12·66	14	15	10·3	9·5360	0·67	
18	8	33	38	18	4	25·02	12	5	31·1	9·5275	0·63	
21	6	26	12	17	50	16·52	+ 6	40	31·8	9·3609	0·38	
26	6	37	25	17	32	27·57	− 0	9	24·8	9·4519	0·38	
29	6	20	54	17	24	3·16	− 3	12	46·0	9·4588	+0·35	

Note on Photographs of Comet d 1902 (*Giacobini*) *taken with the 30-inch Reflector at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

Photographs of this comet have been obtained on 18 nights between January 15 and March 11. Till February 2 the telescope was guided on a star and the comet allowed to trail, but from February 16 the telescope was guided mechanically to allow for the motion of the comet.

The following list of photographs taken is supplementary to that in the *Monthly Notices*, vol. lxiii. No. 3.

Date. 1903.	Exp. m	Date. 1903.	Exp. m
January 15	10	February 23	10, 10
,,	10	25	10
25	10, 7	26	15, 15
28	10, 10	28	15, 15
February 1	15, 15	March 1	10, 15
2	15	3	15, 15
16	20, 15	4	15, 5
17	15, 11	6	10, 10
18	10, 10	11	10, 10
21	10, 10		

Note on Photographs of Comet a 1903 (*Giacobini*) *taken with the 30-inch Reflector at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

Photographs of this comet have been obtained on 14 nights. The telescope was made to follow the stars so that the images of the comet are small trails.

The comet has increased in brightness very fast, and on March 11 had the appearance of a 4th magnitude star.

The following list gives the photographs taken to the present time.

Date. 1903.	Exp. m	Date. 1903.	Exp. m
January 28	10, 10	February 10	9
31	9	,,	9
February 9	9	11	7
,,	9	,,	7

Date. 1903.	Exp. m	Date. 1903.	Exp. m
February 12	5	February 26	2, 2
17	7, 7	March 3	2, 2, 2
18	5, 5	6	2, 2
23	3, 4	11	$1\frac{1}{2}$, $1\frac{1}{2}$
25	2, 3		

On the Desirableness of a Re-investigation of the Problems growing out of the Mean Motion of the Moon. By Simon Newcomb.

Should the question be asked, What is to-day the most important unsolved problem growing out of the celestial motions? a survey of the field could, it seems to me, lead to but one reply. It is that of the discrepancies between the observed mean motion of the Moon and the most exhaustive investigations of the theory of that motion. Twenty-five years have now passed since the publication of my "Researches on the Motion of the Moon,"* and during that time little of a comprehensive and definitive character has been added to the solution of the problem. A general review of it may therefore be appropriate at the present time. Such a review I now attempt.

I.

Beginning in a general way, we call to mind that, when slowly varying discrepancies are found between the predicted mean longitude of the Moon and that given by observation, two explanations are possible. One is that there is an actual deviation of the Moon from the theory on which the prediction is based; the other that the deviation is only an apparent one, due to a slow variation of the Earth's axial rotation, producing a corresponding change in our measure of time. Such being the case, the logical method of proceeding is to make an exhaustive investigation of the inequalities of long period in the mean motion of the Moon which may be produced by every known cause, to introduce any corrections which may be required to the theory, and then to attribute such deviations as remain outstanding to changes in the Earth's rotation. This is what I attempted in the work which I have quoted. The result was that the reconciliation of theory and observations in this way indicated changes in the rotation amounting in their accumulated effect to nearly half a minute of time in one direction or the other in the course of the last 250 years.

Such a result should, before being accepted as final, be tested

* *Washington Observations for* 1875, Appendix II.

e independent method. Two conditions are available: the
ed on the observed motion of *Mercury*, as determined by
tions of its transits across the disc of the Sun; the other
motion of *Jupiter's* first satellite, as determined from
. The first of these conditions is the more precise, and
nly one which any serious attempt has been made to
In my discussion of observed transits of *Mercury* up to
found that seeming variations of the Earth's rotation
dicated, in which there was a fair agreement in algebraic
th those inferred from the motion of the Moon, but of a
ide which, in the general average, was little more than
d as great. Again, in a paper presented to the French
y of Sciences in 1896† I presented the results of a
comparison brought up to the transit of 1894, based on
parison of my new tables of *Mercury* and of the Sun.
e November transits were used in this discussion, the
nes being of scarcely any weight. The results of this
on and their comparison with those inferred from the
of the Moon are summed up in the following table, where
e amount by which the actual Earth must be supposed in
of a uniformly rotating Earth. The dates 1690, 1741,
4 are the means for two transits; the others are those of
vidual transits. In the case of the Moon the results are
lated from the table found on p. 266 of "Researches."

	Δt.		
Date.	Mercury.	Moon.	Diff.
	s s	s	s
1690	+15 ± 10	+30	+15
1723	+ 8 ± 5	+17	+ 9
1741	+ 2 ± 4	+ 5	+ 3
1769	+ 6 ± 5	−12	−18
1789	− 8 ± 3	−18	−10
1802	− 4 ± 3	−16	−12
1822	+ 4 ± 5	− 9	−13
1848	− 7 ± 3	0	+ 7
1864	− 5 ± 2	+ 5	+10
1881	+ 4 ± 2	+16	+12
1894	+ 2 ± 2	+17	+15

ill be seen that in the case of *Mercury* the corrections to
es as indicated by observations are greater than their
e errors in eight out of the twelve cases, and in three
e more than twice the probable error. Although they
lour to the hypothesis of variability in the measure of
oth by their magnitude and their constancy of sign from

Astronomical Papers of the American Ephemeris, vol. i. p. vi.
Comptes Rendus, 1896, tom. i.

1690 to 1769, they are not large enough to prove it. But in any case they are too small to be compatible with the large deviations inferred from the motion of the Moon. We may interpret the column of differences as the outstanding residual errors in the observed times of transits of *Mercury* in case we accept the results from the Moon as real.

The evidence seems almost conclusive that the very improbable deviations in the Earth's rotation inferred from the observation of the Moon are unreal, and that the motion of our satellite is really affected by causes which have, up to the present time, eluded investigation.

II.

The next questions are, What has been done in the way of investigating the possibility of such inequalities on the theoretical side, and by what means may we hope to reach a definitive conclusion on the subject? I need not go over in detail the researches of La Place and Poisson, and need only briefly allude to the work of Hansen, these being sufficiently set forth in the works already quoted. It will suffice to say that Hansen announced two inequalities of long period, due to the action of *Venus*, which he introduces into his tables of the Moon, and which, according to him, completely reconciled theory with observation. But within twenty years of the publication of his tables observation showed a rapidly increasing deviation, and a discussion of observations of occultations before 1750 showed discrepancies of more than 30″ in the latter part of the seventeenth century. It also turned out that one of these inequalities had no foundation in theory, and that Hansen's coefficient was so assigned as to represent observations from 1750 to 1850. This inequality must therefore be thrown out altogether. Four completely independent determinations of the other inequality have been made. Using the notation

g, the mean anomaly of the Moon;
E, the mean longitude of the Earth;
V, the mean longitude of *Venus*;
$A = 18\,V - 16\,E - g$;

these results are the following. All are reduced to the mass $1 \div 408{,}000$ of *Venus*.

Delaunay *	...	...	$16'\cdot34 \sin (A + 29^\circ\cdot5)$
Hansen †	...	...	$15'\cdot34 \sin (A + 30^\circ\cdot2)$
Newcomb ‡	...	...	$14'\cdot80 \sin (A + 30^\circ\cdot5)$
Radau §	...	...	$14'\cdot14 \sin (A + 30^\circ\cdot0)$
Delaunay (cor.)	...	...	$14'\cdot12 \sin (A + 29^\circ\cdot5)$

* *Conn. des Temps*, 1862, addition. † *Tables de la Lune.*
‡ *Astronomical Papers of the American Ephemeris*, vol. v.
§ *Annales de l'Observatoire de Paris: Mémoires*, tom. xxi.

Delaunay's result was corrected by Tisserand, and later by Radau, who concluded that it should be diminished by 2″·2 in consequence of terms omitted in the development. The last of the preceding expressions shows this corrected value.

It is impossible to say, until after a thorough re-investigation of the whole subject on an independent basis, that any of these results should be accepted to the entire exclusion of all the others. A strong presumption in favour of the Delaunay-Radau value is weakened only by the fact that those investigators used substantially the same method of development. But the close agreement of all four, taken in connection with the fact that the methods by which the computations are made are different from the beginning, seems to leave no room for doubt as to the general accuracy of the result, provided that we leave out of consideration quantities of the second order arising from the mutual perturbations of *Venus* and the Earth.*

During the period in question two attempts have been made to discover, by an exhaustive investigation, whether any undiscovered inequalities, due to the action of any planet, can possibly subsist. One of these was made by the writer, the next by Radau. In the first no attempt was made to determine the actual numerical value of the terms investigated, but only to set an upper limit to their possible value. Radau's work is more exhaustive. He attempts to determine the actual numerical value of every inequality due to the action of the planets, but finds none of sufficient magnitude to explain or materially reduce the discrepancy.

The only known causes to which we can attribute changes in the Moon's mean motion are the action of the planets and the action arising from the deviation of the Earth from a spherical form. Both actions have, to all appearances, been exhaustively investigated. Where, then, are we to look for a solution of the enigma? The whole question must be re-investigated *ab initio* with a view to discovering whether any omission or error has been made, either in the theory or in the complex process of comparing it with observations. As a sort of forlorn hope, it seems advisable to determine whether by any possibility the mutual perturbations of the Earth and *Venus* can give rise to a sensible term in the Moon's mean longitude. Moreover, every

* In this connection a curious coincidence may be pointed out. In my "Researches" I showed that if we simply changed the sign of the constant term in the preceding expression, so that the argument should be A − 30° instead of A + 30°, the agreement between theory and observation would be fairly good throughout the entire period of 250 years of observation. So striking a coincidence led a writer in the *Vierteljahrsschrift der Ast. Gesellschaft* to accept the conclusion that the change was real, and that there was an error of sign in the term in question as used by Hansen. But this conclusion seems quite out of the question; in fact, I investigated it thoroughly before the publication of my work. It would seem, therefore, that we can look upon the case only as a singular coincidence.

investigator who takes up the theory may well make a thorough inquiry into the question of the possibility of some periodic terms having been overlooked in the discussions so far made.

III.

What has been said in Section I. rests on comparisons of the observed mean longitude of the Moon at widely distant epochs with theory, the results of which are summed up on pages 264-266 of the "Researches" already alluded to. This comparison, though it seems fairly certain so far as general facts are concerned, may still need not unimportant corrections, especially during the period 1750–1840. It is remarkable that the history of the Moon's mean motion is more accurately known during the seventy-five years before 1750 than it is during the period 1750-1840, when the comparison of Greenwich observations with Hansen's tables commences. The results which I have cited rest on the hypothesis that during this period Hansen's tables represent the observations. In view of the fact that the tables are based on these observations, and that the few scattered comparisons which Hansen has given do not show large systematic deviations, we would seem to be justified in provisionally accepting this agreement. At the same time, with so enigmatical a problem before us, everything must be the subject of critical inquiry; and I deem it quite possible that from time to time the tables may be found to deviate from observations about the beginning of the nineteenth century to an extent greater than has been supposed.

Feeling the importance of the comparison in question, the writer, some twenty years ago, commenced and carried nearly to an end a work which he was obliged to suspend without bringing it to a definitive conclusion. It was that of comparing Hansen's tables with observations of occultations of stars since 1750. Occultations of stars by the Moon were taken as the basis for the work, for the reason that the results are less subject to systematic error, especially the personal error arising from comparing the limb of the Moon with a star, than are meridian observations. But the results are still subject to a not inconsiderable accidental error arising from the inequalities of the lunar surface. It is therefore desirable to supplement them by the Greenwich Meridian Observations. These, up to 1830, were reduced by Airy, and the results published in his monumental work fifty-five years ago. In a subsequent work the reductions were carried forward to 1851. The results were compared with Damoiseau's tables, to which were applied a number of corrections.

It does not seem that any certain result can be derived from this comparison at the present time. After making all allowances for the possible errors of the corrected tables and the probable errors of observation, the outstanding differences are larger than

be anticipated. Some years ago I endeavoured to investi-
he subject by applying to the tables used by Airy the
al corrections necessary to reduce them to those of Hansen.
ese corrections were too small to materially diminish the
ancies. The case is rendered more embarrassing by the
at when we take the few comparisons given by Hansen,*
mpare them individually with those made by Airy, using
me observations, we can trace only the slightest relation-
etween the two.

an example of this, I have made the following com-
n of the two results at certain dates when the Moon was
the one or the other solstice, so that the residuals in
ade and latitude used by Airy should nearly correspond to
als in R.A. and Dec. which are given by Hansen. Both
e given in the sense Theory *minus* Obs.

		Δ Long.		Δ Lat.	
		Airy.	Hansen.	Airy.	Hansen.
		″	″	″	″
1751 Oct.	24	+ 2·1	+ 1·4	− 3·1	− 1·5
	25	− 0·3	+ 3·5	− 6·5	− 5·2
Nov.	7	+ 15·2	+ 1·6	− 8·3	− 7·0
1752 Feb.	23	+ 3·8	− 7·5	+ 2·2	+ 2·5
	25	+ 15·4	+ 0·2	+ 6·0	+ 3·9
Mar.	6	− 3·4	− 6·6	+ 5·0	+ 6·1
	7	+ 0·2	− 3·7	+ 5·3	+ 2·8
	9	+ 7·2	+ 0·7	+ 10·3	+ 3·7
Oct.	12	− 7·9	− 3·5	+ 12·7	+ 11·2
	13	− 8·1	− 2·7	− 5·2	− 6·0
	25	+ 3·1	− 0·2	− 2·5	− 7·7
	27	+ 1·7	+ 5·3	− 3·6	− 4·4
1824 Mar.	8	+ 7·7	0·0	− 0·2	+ 1·1
	9	+ 0·6	− 2·9	+ 0·3	− 0·6
Aug.	31	+ 8·0	+ 4·7	+ 6·3	+ 0·8
Sept.	1	− 1·3	+ 0·5	+ 2·8	− 2·5
	2	− 4·0	+ 0·7	+ 8·1	− 0·6
	15	+ 4·7	+ 0·7	+ 0·6	+ 0·4

hen studying this subject twenty years ago I satisfied
f that these discrepancies could not be materially diminished
plying to Airy's results the differences between Damoiseau's
y, as corrected by Airy, and that of Hansen.

he investigation of the subject is rendered more difficult by
act that no details of Hansen's comparison exist. The

* *Monthly Notices R.A.S.*, xv. pp. 2–7.

differences between theory and observation are all he gives. We find no statement as to methods or data of reduction, or the actually observed or computed positions of the Moon. Some twenty years ago, during a visit to Leipzig, I made an unavailing attempt to find the material in question among Hansen's papers, which are there preserved. A more thorough search might, however, bring something to light.

Whatever might be the outcome of such an investigation, it is very clear that Airy's reductions need a thorough revision, and that the results should be compared directly with Hansen's tables, the latter being corrected for their principal known errors. The great improvement made during the last half-century in our knowledge of the positions of the fixed stars, and in the data and methods of reduction generally, forms a sufficient reason for the suggested revision.

IV.

The question of correcting Hansen's tables before deriving any results from them is an important one. They undoubtedly need a number of corrections. Those first in importance, if we could only decide upon them, would comprise terms of long period in the mean longitude. But the nature of these terms is one of the very matters to be investigated, and it is therefore useless to make purely theoretical corrections that do not represent observations.

Among the corrections of short period, the most important is that required by Hansen's parallactic inequality. This is about 2″ too large in his tables. The existence of such an error is difficult to account for if the inequality in question was determined by a direct comparison of the theory with observations. A curious fact in this connection is that if the value which Hansen uses as applicable to his disturbed mean anomaly had been used as an inequality in the true longitude, the result would have been nearly correct. The question whether Hansen took the one coefficient as equivalent to the other is not now of practical importance. What is of practical importance is to correct the tables for the error, which is more troublesome than any other in the comparison with observations. I did not do this in my former "Researches," because the amount of the correction was still uncertain; and it is easier to make a correction like this, once for all, through a long period than it is to proceed by successive patching up.

I believe that all the other corrections to the tables are, individually, only fractions of a second, and will, in their total effect, rarely, if ever, rise to 2″. This total will also be a rapidly oscillating quantity, as often positive as negative. It can therefore not affect our conclusions as to the terms of long period.

V.

The importance of the questions suggested in the preceding discussion is emphasised by the growing need of new tables of the Moon. During the half-century which has elapsed since the completion of Hansen's tables great progress has been made in determining the relations and numerical values of the various elements on which such tables must be based. The great stumbling-block in the way of a perfectly satisfactory basis is the enigma of the variations of long period. The solution of this enigma requires two processes. One is the thorough investigation of the mathematical theory of the subject, the other the discussion and comparison of observations.

In considering the mathematical side of the work the first question is that of method. Thirty years ago I proposed that the problem should be attacked in the most rigorous way by regarding the twelve elements of the Sun and Moon as simultaneously variable in the general Lagrangian equations of motion. An attempt by this method is found in a memoir on the action of the planets on the Moon, of which the work was actually done in 1871–72, though the memoir was not published until 1894. I am now convinced that this method requires developments too complex to practically be carried through. The developments actually found in it can, however, to a large extent, be used in a modification which leads to what is, in effect, a continuation of Delaunay's method, and is practically identical with the method adopted by Hill and Radau. What is wanted reduces itself to a rigorous reconstruction of the fundamental equations of this method.

On the observational side the question may arise whether it is not better to await the completion of an improved theory of the Sun's action on the Moon—for example, that which Professor E. W. Brown is now bringing to a conclusion—before attempting correction of the lunar elements by observations. So far as the terms of long period are concerned it is clear to me that this question must be answered in the negative. A mapping out of these deviations, as observed through a period of 250 years, may afford valuable suggestions as to where we must look for their cause. Moreover, the results that may be reached will be practically as good when Hansen's tables are used, with a few preliminary corrections, as if we had the most accurate tables possible.

The case is not so strong for going on to the immediate determination of the lunar elements by taking Hansen's tables as the basis of comparison. If printed tables, based on Brown's theory, were available, it would be better to use them. Yet the advantage thus gained would not be so great as to justify a very long delay in order to realise it. The theoretical errors of Hansen's tables, some easily corrected faults aside, are so small

that they would be completely eliminated in the mean of so long a series of observations as is now available.

More serious is the fact that the eccentricity and inclination which we should derive by the suggested plan would be those which belong to Hansen's system of variables, and not to the new theory. But it is so simple a matter to reduce one of these sets of elements to the other that this does not constitute a strong objection.

The following seems to me the logical order of proceeding as the case now stands :

1. A new investigation of the possible inequalities due to the action of the planets.

2. The completion of my comparison of Hansen's tables with occultations, in order to determine the actual deviations of long period.

3. The construction of provisional tables based on Brown's theory.

4. The re-reduction of the Greenwich Meridian observations since 1750.

5. The comparison of the results of this re-reduction with the tables of Brown or of Hansen.

The works here suggested involve such an amount of labour that a system of international co-operation in their prosecution seems desirable. The question whether my estimate of their importance is correct, and, if so, whether such co-operation is necessary and practicable, is one which I should be glad to see discussed.

Errata in Annual Report, Monthly Notices, vol. lxiii. No. 4 (Obituary of Col. Cooper).

Page 197, line 14 from bottom, *for* 1872 *read* 1863.

„ line 4 from bottom, *for* 1876 *read* 1874.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXIII. APRIL 8, 1903. No. 6

Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

Thomas Frederick Bowers, B.A., Woolwich Polytechnic School, and Darenth, Little Heath, Old Charlton, S.E.;
Frederick Hugh Capron, 38 Avenue Road, Highgate, N.;
Lieut. Kenneth Essex Edgeworth, R.E., Stanhope Lines, Aldershot;
Alphonso King, 93 Victoria Road East, Leicester;
William Tillar, St. Hilda's, Westbourne Road, West Kirby, Cheshire;
Gilbert Thomas Walker, M.A., Assistant Reporter in Meteorology to the Government of India; and
Pollard Wilkinson, B.A., B.Sc., 21 Ashmere Grove, Ipswich,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as Fellow of the Society, the name of the proposer from personal knowledge being appended:—

Alfred Pratt, B.A., B.Sc., 14 Endwell Road, Brockley, S.E. (proposed by Thomas Lewis).

Sixty-three presents were announced as having been received since the last meeting, including amongst others:—

L. Brenner, Jupiter-Beobachtungen auf der Manora Sternwarte 1898–1901, presented by the author; Breslau, Königliche

Sternwarte, Mittheilungen, II., presented by the Observatory; Brussels, Société belge d'Astronomie, Bulletin, Année 1–8, presented by the Society; Carte photographique du Ciel, 33 charts, presented by the French Government; Osborne Reynolds, The Sub-mechanics of the Universe, presented by the Royal Society; T. N. Thiele, Theory of Observations, presented by the author; Washburn Observatory Publications, vol. xi. (meridian observations for stellar parallax), presented by the Observatory; L. Weinek, Definitive Resultate aus den Prager Polhöhen-Messungen, presented by the Prague Observatory.

Preliminary Note on the Possible Existence of two Independent Stellar Systems. By F. A. Bellamy and H. H. Turner, D.Sc., F.R.S., Savilian Professor.

The authors desire to withdraw this paper. It was intimated in the January number of the *Monthly Notices* that some numerical corrections had been found necessary; but it was not possible to say at the time how far the main conclusions would be affected. On going carefully through the work it is found that the correction is unfortunately vital, and the trace of a double polarity which now remains is practically negligible

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Note on a New Star in the Constellation of Gemini.
By F. A. Bellamy.

The circumstances attending the discovery of a *Nova* are perhaps of sufficient general interest to warrant their being given in some detail. On the night of March 16 I was exposing plates in zone $+30°$ required to complete that zone for the Astrographic Survey, and among the few required was that with the coordinates of the centre of the plate equal to $6^h\ 36^m\ +30°$. Having some difficulty in identifying the star for which I had set the micrometer scales and instrument, owing to its faintness (8·6) in an illuminated field, I decided to use a bright star which I thought was in the same field of view and less than half a réseau interval away. I accordingly moved the scales and brought the bright star into bisection, and exposed the plate for 6^m, and also gave it 4^m and 20^s.

Whilst exposing the plate Mr. H. C. Plummer came into the Dome and asked if he could help. I remarked to him that I had

some trouble in picking up the star as given in the catalogue, and said I was using a bright star of the seventh magnitude—a magnitude distinctly visible in a bright field in the 12¼-inch O.G.—and had moved the scale to that star ; would he alter my setting in y in the note-book and write $+2'\ 40''$ instead of $+5'\ 0''$. I further said that I should finish the exposures, though I expected I should have to take the region again, as I believed there was some error in the catalogue star (B.D. $+30°$, 1306), as neither the setting nor the magnitude agreed with the bright star I used ; and I could not then think why an 8·6 star had been selected when there was a seventh-magnitude star so near it, and suspected a transposition of figures intended for 6·8 mag. I developed the plate (No. 2193) the next day and examined it the following day, when we found that I had erroneously set the telescope by 1^m in hour-angle, and so used another star. This being beyond the limits of error in setting permissible, the plate was rejected without further examination and put among the rejected plates in the lecture room, and the region marked to be taken again.

On March 24 Professor Turner was going through all the plates recently taken. I may say that we had had a batch of plates which were not quite so rapid as usual, and this, with some indifferent weather, put a number of plates on the border line between acceptance and rejection. After settling which were to be rejected Professor Turner took them to the lecture room, and in putting them with others found three plates apparently rejected by mistake, as no reason was written on the envelope. He took them upstairs for inquiry and was told that No. 2193 had been rejected for wrong setting, though the notification of this fact had been accidentally omitted. To guard against a repetition of the error in setting, he took down an "overlapping" plate from the rack, viz. Plate 963, Centre $+29°\ 6^h\ 40^m$, exposed 1896 January 28, and saw at once that there was a strange object on Plate 2193, which had been used as a guiding star and accounted for the wrong setting. The following plates were also examined and no trace of this object found :—

Plate.	Centre.			Exposed.
	°	h	m	
1903	+30	6	36	1902 Mar. 3
2126	,,	,,		1903 Feb. 21
2154	+31	6	40	1903 Feb. 28

Chandler's third catalogue of variable stars was consulted without result, and subsequent lists of new variables as given in the *Astronomical Journal*. The distances between the three images on Plate 2193 were measured and compared with those of stars with which they were found to agree, so that there was evidence against the strange object being a planet. Professor Turner measured its position on Plate 2193 by use of four com-

parison stars (Leiden 2763, 2803, 2782, 2786) on the afternoon of March 24, and found the following place for 1900·0:

R.A. $= 6^h\ 37^m\ 48^s{\cdot}86$ $\quad \delta = +30°\ 2'\ 39''$

After sunset the clouds cleared, and on setting carefully for the plate centre $6^h\ 36^m\ +30°$ by means of the adopted guiding star, Cambridge 3447 or B.D. + 30° 1306, he saw the strange object at once. He exposed a plate (No. 2205), and after securing the exposure measured the distance of the object from the guiding star in R.A. by transit in Decl. by the scale for "setting" The differences were found to agree closely with those found by measurement on Plate 2193 during the afternoon.

As it seemed by this time probable that the object was a *Nova*, post-cards were sent off at once to several spectroscopic observers; and early the next morning a telegram despatched to Kiel.

Positions of the Nova and Surrounding Stars.

It was considered advisable to measure the position of the new star, and also as many stars as were visible on the plate within a radius of about three réseau intervals (15′), to assist others in measuring or examining photographs of this region already taken, or for use in visual work with a telescope.

I have accordingly measured all these stars on Plate 2205, only twelve in number, and probably none fainter than about the tenth magnitude; also forty-nine stars, which appear in the Cambridge and Leiden A.G.C.s, used for the determination of the constants for the plate. It is not necessary to give the measures of the latter—I measured them in the direct and reversed positions and took the mean—nor the equations which give for the final constants.

Plate 2205, 1903 March 24, Sid. Time of Exposure $8^h\ 41^m\ 35^s$

a	*b*	*c*	*d*	*e*	*f*
−·00024	+·00567	−·1416	−·00563	−·00051	−·1625

As a check on the work the residuals were formed for each of the forty-nine stars, but these need not be given.

The third exposure, being 4^m, was measured, as it showed the most satisfactory images; the night was not fine.

The uncorrected measures of the *Nova* are $\overset{x}{17}{\cdot}6455$, $\overset{y}{13}{\cdot}2695$.

The Oxford coordinates, ξ' and η', and the corresponding R.A.s and Decs. for the *Nova*, these twelve stars, and for Camb. 3447, 3455, and 3467 will be found included in Table I. It should be stated here that the position of the *Nova* for epoch 1900·0 derived from this plate (2205) is

R.A.	N. Dec.
$6^h\ 37^m\ 48^s{\cdot}96$	$30°\ 2'\ 38''{\cdot}9$

TABLE I.

Stars near the Nova, as found from Plate 2205; *R.A.* $6^h\ 36^m + 30°$. *Exposed* 1903 *March* 24.

B.D.	Oxford Magnitude. Measured Diameter.	Equivalent Magnitude.	Deduced. ξ'. 1900·0.	η'. 1900·0.	R.A. 1900·0.	N. Dec. 1900·0.
					h m s	° ′ ″
1306, 8·6	18·5	8·3	14·3590	13·9982	6 36 31·40	30 4 59·2
	9·5	10·2	14·7767	17·0656	6 36 41·19	30 20 19·2
	10·5	10·1	14·8166	13·2831	6 36 41·96	30 1 24·5
	16·0	9·6	16·1796	13·7041	6 37 13·47	30 3 30·0
	11·0	10·1	16·6737	13·3785	6 37 24·86	30 1 51·6
1324, 9·5	9·0	10·3	16·7068	10·8945	6 37 25·45	29 49 26·6
	9·0	10·3	16·8126	12·4133	6 37 28·00	29 57 2·2
	8·5	10·3	17·2151	11·5471	6 37 37·23	29 52 41·9
	30	8·16	17·7160	13·5390	6 37 48·96	30 2 38·9
	8·5	10·3	17·9231	11·2601	6 37 53·53	29 51 15·3
	9·5	10·2	19·3946	14·5225	6 38 27·86	30 7 31·6
	11·5	10·0	19·3956	14·4961	6 38 27·88	30 7 23·4
	9·5	10·2	19·4201	12·5416	6 38 28·21	29 57 37·3
	13·0	9·9	19·8411	12·4594	6 38 37·91	29 57 11·9
1316, 9·0	18·0	9·4	19·8365	15·3755	6 38 38·18	30 11 46·7
	16·0	9·6	20·0256	11·2296	6 38 42·00	29 51 2·7

he earlier plate, 2193, would have given nearly twice as
r stars within 15′ of the *Nova*, but time has not allowed of
easurement and reduction in the midst of other pressing
.

The Magnitudes from the Measured Diameters.

o determine the magnitudes the formula used was that
ned, provisionally, from a large number of plates by
ssor Turner.

iameter = 13(10·8 — magnitude) $+x$(12·3 — mag.) × 0·3

ng a constant to be determined from each plate and expo-
the magnitudes being those of Argelander. Since (12·3
g.) × 0·3 is approximately unity for the mean of the stars
e plate, x is found from the mean excess of diameter over
rst term.
or Plate 2193 (March 16) x, from forty stars ranging from
9·5, came out to be −4·4, the resulting magnitude of the
being

6·93 from the first exposure of 6 minutes.

x for the second exposure is $-7{\cdot}2$, the resulting magnitude be

6·69 from the second exposure of 4 minutes.

The third exposure is not shown for all stars.

Plate 2205, *exposed March* 24.

Similarly, for this plate x was determined to be $-8{\cdot}0$ for third exposure; the other two have not yet been measured.

The mean measured diameter of the *Nova* is 30·0 (unit = 0″ and the resulting magnitude obtained is

8·16 from the third exposure of 4 minutes.

In the same way the equivalent magnitudes in Table I. h been obtained.

Saturday, April 4.—From a careful comparison of the *N* with +30° 1306, 8·6, I estimated its magnitude to be brighter, *i.e.* 8·4; the Moon was near. Two plates were a exposed.

April 23.—In response to applications for positions of faint stars than the 11th mag. within 15′ of the *Nova*, a plate is bei measured which contains stars to the 14th or 15th mag., a the results will probably be communicated to the Society at t May meeting.

University Observatory, Oxford:
1903 *April* 4.

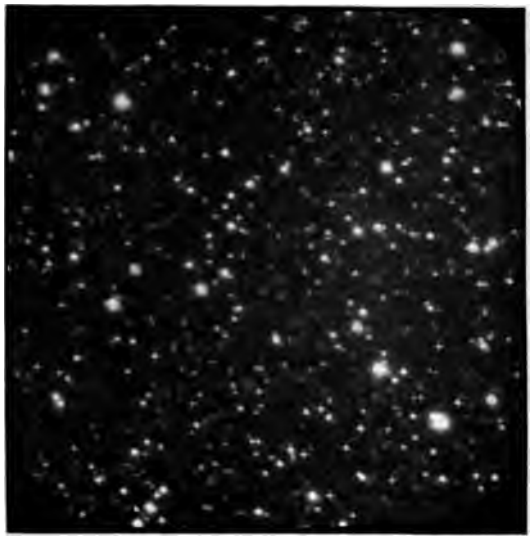
The Place of Nova Geminorum. By Max Wolf, Ph.D.

I send to the Society a direct enlargement of Dugan's pl of February 16 of the region of Nova *Geminorum*. I compa this plate under the stereo-comparator with a plate of Mr. Go of April 3. There is nothing exactly at the place of the No but extremely near to it is a starlike object of about the sixtee magnitude, and this extends over the place of the Nova, so t the Nova may be a part of this chain-like object. The origi plate was exposed for three hours with my 6-inch Voigtlan lens. It is enlarged about five times. The exact place on accompanying photograph (Plate 13) is shown on the key 1 by the intersection of the two lines near the centre.

Königstuhl: 1903 *April* 6.

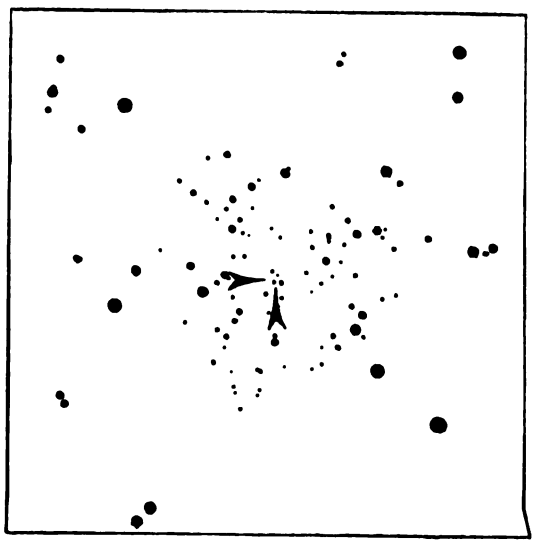
N

E W



S

REGION OF NOVA GEMINORUM.—MAX WOLF
1903 FEB. $16^d\ 9^h\ 3^m.1$ to $12^h\ 11^m.1$.



KEY MAP.

Rotation Periods of the Markings on Jupiter.

By W. F. Denning.

seems desirable to trace, as closely as possible, the markings *piter* at successive oppositions, so that the changeable ies of the different currents may be determined and com-

By this means it will ultimately become possible to ain whether the motions are subject to regular periodical ons in rate or whether they merely partake of the cha- of atmospheric vagaries, and are not reducible to any law. ontinued observations of the markings may also furnish evidence as to their durations as visible objects, and also question of possibly recurrent outbreaks in certain lati- after intervals of comparative quiescence.

a contribution to a consecutive history of this planet's phenomena, I have compiled the following summary of rotation periods computed from observations at Bristol, ing over the five years 1898 to 1902 inclusive, with a 1 Browning-With reflecting telescope and one of Steinheil's centric micrometer oculars" of $\frac{1}{4}$-inch equivalent focus, a power of 312. Magnifiers of 252, 332, and 488 were nally employed, but the one of 312 was usually found the erviceable and efficient.

ring the five years named the planet was placed south of uator (in 1900 and 1901 from $19\frac{1}{2}°$ to $23\frac{1}{2}°$ S.), and re in an unfavourable position for European observers. burb of Bishopston, from which my observations were lies due north of Bristol, so that the definition was some- much impaired by the situation of *Jupiter* immediately e centre and amid the vapours of a populous city.

what extent low altitude affected the telescopic images e judged from the following figures. The planet was ed on 328 nights, and on 292 of these a note was made e quality of the seeing.

Definition very good	25	nights.
Good	52	,,
Fair	66	,,
Bad	93	,,
Very bad	56	,,

would be premature to discuss the results fully, but it may tioned that during the five years the mean rotation periods markings varied as under :—

	h	m	s		h	m	s
quatorial spots	9	50	$23\frac{1}{2}$	to	9	50	29
. tropical spots	9	55	$26\frac{1}{2}$	to	9	55	$31\frac{1}{2}$
. and N.N. temperate spots	9	55	50	to	9	55	$56\frac{1}{2}$
temperate spots	9	55	$18\frac{1}{2}$	to	9	55	$20\frac{1}{2}$
reat red spot	9	55	42	to	9	55	39

The great red spot, after exhibiting a retarded rate of velocity between 1878 ($9^h\ 55^m\ 33^s{\cdot}7$) and 1899 ($9^h\ 55^m\ 41^s{\cdot}9$), showed evident signs of acceleration in 1900. This became more strongly pronounced in 1901, during which year the object retained a stationary longitude (45°) relatively to System II. of Marth-Crommelin's ephemerides based on a period of $9^h\ 55^m\ 40^s{\cdot}63$. The acceleration further developed in 1902, and brought about a reduction in the rotation period of 3 seconds as compared with that in 1899, and the longitude of the spot on 1902 December 31 became 36°·3. This marking has presented an exceedingly faint, though somewhat variable, aspect in recent years, and its oval shape has only been discernible under the best conditions. For this reason satisfactory transits are not often obtainable, but a good substitute is found in the conspicuous hollow or bay on the S. side of the great S. equatorial belt, which has precisely the same longitude and rate of velocity as the red spot, and is undoubtedly very closely connected with that object.

It should be remarked that the differences in the rotation periods shown in the above table are the means derived from several objects in the same current. The individual objects exhibited larger discordances, for even at the same period the rate of motion of a current is very far from being equable throughout its circumference. To show how far this is the case it will be sufficient to give the extreme differences in rotation period observed in regard to the equatorial spots in four years :—

Summary of mean Rotation Periods of the Principal Mar

Description of Markings.	Approximate Latitude.	1898. Rotation Period.	1898. No. of Spots.	1899. Rotation Period.	1899. No. Spo
	° °	h m s		h m s	
N.N. temperate spots N. temperate spots ...	+40 to +25	9 55 50·1	2	9 55 29·8 9 55 53·5	
N. tropical spots ...	+14	9 55 26·3	3	9 55 28·8	
Equatorial spots S. side N. belt ...	+ 6	9 50 26·8	1	...	
Equatorial spots N. side S. belt ...	− 5	9 50 23·6	23	9 50 24·6	
Great red spot ...	−20	9 55 41·8	1	9 55 41·9	
S. temperate spots ...	−27 to −33	9 55 20·5	4	9 55 18·6	
S.S. temperate spots ...	−35 to −40	9 55 14·0 9 55 8·6	2 2	9 55 9·2	
Date of observations ...		Mar.–July		June–Sep	
Nights of observation ...		51		76	
Transits recorded ...		280		668	

	Spot with Minimum Period. h m s	Spot with Maximum Period. h m s	Difference. sec.
1898	9 50 16·9	9 50 33·2	16·3
1899	9 50 18·0	9 50 35·0	17·0
1901	9 50 25·1	9 50 35·0	9·9
1902	9 50 24·4	9 50 29·1	4·7

From these figures it would appear that the velocity of the equatorial current displayed a more even rate generally in 1902 than in 1898 and 1899.

During the last few years I have frequently looked for a return of the rapidly moving spots observed in the N. temperate belt of *Jupiter* in 1880 and 1891, but have not certainly succeeded in recovering them. Both in 1901 and 1902 the region of the planet in about N. latitude 25°–40° exhibited a very disturbed condition, and dark spots were abundant; but as far as could be observed they were all controlled by a very slow rate of motion. Confused definition and periods of unfavourable weather, however, prevented some of these markings from being followed as satisfactorily as could have been wished. On 1902 November 18 I observed two well-defined dark spots (also seen by the Rev. T. E. R. Phillips at Croydon) in the N. temperate region, the f. one of which occupied same longitude as the centre of the red spot hollow. A week later—on November 25—the two spots were missing: they had either moved rapidly westwards or disappeared altogether; but much unfavourable weather followed, and the objects alluded to were never seen again.

ings on Jupiter in the years 1898 *to* 1902 *inclusive.*

1900. Rotation Period. h m s	1900. No. of Spots.	1901. Rotation Period. h m s	1901. No. of Spots.	1902. Rotation Period. h m s	1902. No. of Spots.
} ...	...	9 55 50·2	6	9 55 56·5	9
9 55 30·0	17	9 55 31·6	1	9 55 29·8	10
...	...	...	...	9 50 28·5	1
9 50 24·1	18	9 50 29·1	28	9 50 26·7	24
9 55 41 7	1	9 55 40·9	1	9 55 39·0	1
...	...	9 55 19·7	1	9 55 18·7	7
...	...	...	...	...	...

899 Dec.–1900 Mar.	May–Nov.	1902 June–1903 Jan
36	76	89
307	547	1005

Of the total number (2,807) of transits 1,855 equatorial spots, while 952 were of other markings. T immediately south of the equator are generally more a and conspicuous than those lying north of it.

Bishopston, Bristol:
1903 *March* 18.

On the Orbit of Σ 2525. By W. Bowyer.

(*Communicated by W. H. M. Christie.*)

This star is

B.D. +27°, No. 3391, R.A. $19^h\ 22^m\ 30^s$, N.P.D. 62° 52′ } 1900
Mags. 7·5 and 7·7 (Σ)

In vol. liii., *Monthly Notices*, 1892 November, M computed an orbit of this double star from the obse extending from 1828 to 1892, the period obtained bein years.

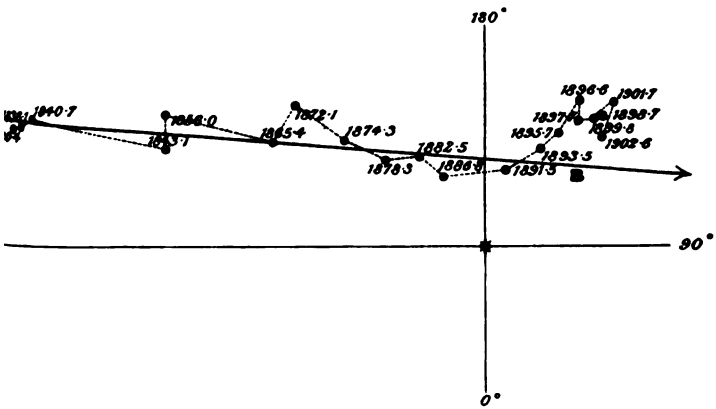
This orbit was merely intended to draw attention to t for the material at Mr. Gore's command was really insuff discriminate between orbital and rectilinear motion, the tion of H. Struve in 1889 not being then publishe magnitudes of the components being so nearly equal, impossible to tell from the observations of 1886, 189 whether the secondary star had swept through the two qu 180° to 0° and had reached the fourth quadrant in 18 whether it had simply continued its motion from A to B, a in fig. 1.

For the purposes of the present paper all available tions have been collected. The measures being in gener what discordant, it seemed advisable to group them weights according to the number of nights. The mean pl shown in the following table. The abbreviations used a

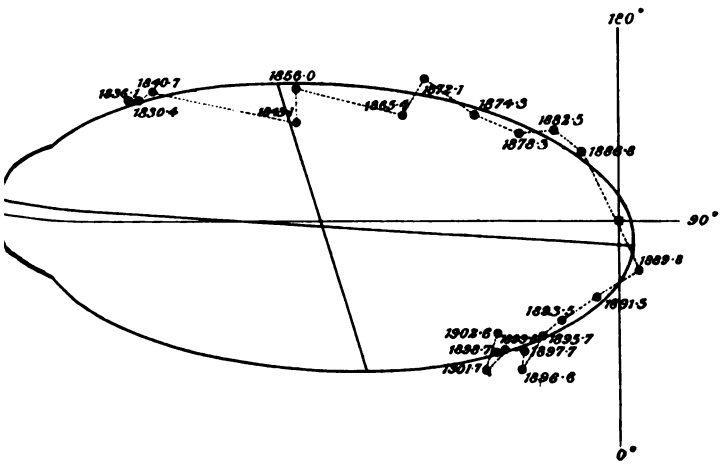
Σ, W. Struve; OΣ, O. Struve; HΣ, H. Struve Dembowski; Schiap., Schiaparelli.

Date.	Position Angle.	Distance.	Observer and Number of
	°	″	
1830·43	255·9	1·33	Σ 5.
1836·14	255·5	1·30	Σ 2.
1840·67	253·5	1·27	Dawes 1, OΣ 2.
1843·06	252·5	0·89	Maedler 2.
1855·95	247·0	0·92	OΣ 1, Secchi 2.
1865·39	243·0	0·63	Dem. 7, OΣ 2, Engl Secchi 1.

Σ 2525
FIG. 1.



Σ 2525 (Apparent Ellipse)
FIG. 2.



SCALE
0·0 0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9 1·0

Date.	Position Angle.	Distance.	Observer and Number of Nights.
1872·08	233°6	0″63	Dem. 1, OΣ 1.
1874·34	233·0	0·47	Wilson and Seabroke 9, Ferrari 1, Gledhill 1, Dem. 3, Schiap. 5.
1878·33	228·6	0·35	Schiap. 5, Dem. 1, Hall 3, Seabroke 2.
1882·52	215·8	0·29	Schiap. 10, Doberck 2, Engelmann 8, Perrine 4.
1886·80	210·0	0·22	Schiap. 2, Hall 1.
1887·71	single		Schiap. 1.
1888·78	single		HΣ 2.
1889·78	24·1	0·15 ±	HΣ 1.
1891·49	343·8	0·21	β 4, Hough 1, HΣ 1.
1893·46	329·3	0·30	β 1, Comstock 3.
1895·68	326·2	0 36	Dyson 1, Lewis 2, Glasenapp 2, Comstock 3.
1896·63	326·9	0·47	Lewis 4, Comstock 3.
1897·66	323·3	0·42	Lewis 5, Aitken 3.
1898·65	317·9	0·47	Lewis 3, Bryant 1.
1899·79	319·1	0·45	Aitken 3, Lewis 4, Bryant 3, Bowyer 3.
1901·65	318·1	0·52	Lewis 3, Bowyer 1.
1902·63	313·2	0·43	Lewis 1, Bowyer 3.

These means are plotted in fig. 1 (Plate 14) on the assumption that the motion is rectilinear; and it is evident that up to 1893 the measures are well satisfied by an annual motion of ″·024 along the line AB in the direction of 85°·5.

The following is an analysis of this motion :—

From 1830·4–1843·1 an annual motion of ″·030
1843·1–1856·0 „ „ „ „ ·025
1856·0–1872·1 „ „ „ „ ·021
1872·1–1882·5 „ „ „ „ ·019
1882·5–1891·5 „ „ „ „ ·027
1891·5–1902·6 „ „ „ „ ·014

The observations since 1893, however, cannot be thus satisfied. Moreover, the pair has been under constant observation at Greenwich, and although the difference of magnitude is but slight, observers are unanimous in placing the companion in the fourth quadrant.

In fig. 2 (Plate 14) the recent observations are plotted in the fourth quadrant and the apparent ellipse drawn. This also explains why in 1887 and 1888 no duplicity could be detected, and that

sure of 1889 is in the first quadrant, as recorded by
n Struve. No doubt can then remain that the pair form
y system.

investigation of the apparent ellipse by Herschel's
d yields the following elements of the true ellipse :—

$e = .957$ $\quad a = 1''.41$
$\Omega = 25° 0'$ $\quad T = 1887.9$
$\gamma = 57° 4'$ $\quad P = 306.7$ years
$\lambda = 76° 23'$

The following table gives a comparison between the observ
sitions and the computed, using the above elements :—

Date.	Angle Observed.	Angle Computed.	θ O−C.	Dist. Observed.	Dist. Computed.
	°	°	°	″	″
1830·4	255·9	255·7	+ 0·2	1·33	1·30
36·1	255·5	254·2	+ 1·3	1·30	1·25
40·7	253·5	253·0	+ 0·5	1·27	1·20
43·1	252·5	252·5	0·0	0·89	1·16
56·0	247·0	249·2	− 2·2	0·92	1·05
65·4	243·0	244·4	− 1·4	0·63	0·86
72·1	233·6	240·4	− 6·8	0·63	0·71
74·3	233·0	238·7	− 5·7	0·47	0·66
78·3	228·6	234·5	− 5·9	0·35	0·54
82·5	215·8	227·4	−11·6	0·29	0·40
86·8	210·0	203·2	+ 6·8	0·22	0·14
87·7	single	135·7	...	...	0·05
88·8	single	14·6	...	...	0·12
89·8	241	359·4	+24·7	0·15 ±	0·1
91·5	343·8	346·6	− 2·8	0·21	0·2
93·5	329·3	335·3	− 6·0	0·30	0·
95·7	326·2	328·2	− 2·0	0·36	c
96·6	326·9	325·9	+ 1·0	0·47	
97·7	323·3	323·4	− 0·1	0·42	
98·7	317·9	321·2	− 3·3	0·47	
99·8	319·1	319·3	− 0·2	0·45	
1901·7	318·1	316·3	+ 1·8	0·52	
02·6	313·2	315·1	− 1·9	0·43	

...ir being now separated by 0″·5 is
... observers, and should

A Standard Scale for Telescopic Observation.

By Percival Lowell.

(*Communicated by the Secretaries.*)

rofessor W. H. Pickering was quite right in calling attention
origin of "A Standard Scale for Telescopic Observation."
s devised by him, although he modestly does not mention
lf directly in the matter; and he deserves great credit for
g devised it, as it is the only absolute scale—that is, the
ne independent of the personal equation—which has yet
suggested. For large telescopes it needs to be compressed
lower and expanded at the upper end, as it is a function
aperture, and for exactness it must be supplemented by
rd of the bodily motion as shown by Mr. A. E. Douglass:
osphere, Telescope, and Observer" (*Popular Astronomy*,
, and "Scales of Seeing" (*Popular Astronomy*, 1898).
nce it was first put in practice—at Arequipa and Flagstaff—
further knowledge about what makes good or bad seeing
en obtained through the study of the air-currents by Mr.
Douglass, for some years connected with this observatory.
s research we are indebted for the practical results, though
r the original detection of the air-currents which make or
he seeing, and for the practical results which flow from
observation. In the course of this research it has thus been
, for example, that clear-cutness of the limb is not a sure
planetary observations. The air-currents may be such as
e a sharp limb and poor detail definition, or a poor limb
od detail, or to show both limb and detail clearly. It
to be a matter of the size of the waves. An observer,
g of a planet as a whole, might easily suppose he was
seeing good enough to show certain detail if it existed,
as he was not; and *vice versa* he might distrust realities as
ns.

seems to be absolutely necessary to refer to the stars as a
ion for the reason that otherwise too much is left to the
mination of the observer. Reference to the condition of
rminator or to any other special feature is too much a
r of individual skill to be generally advisable. A scale to
iversal must be as simple and impersonal in practice as it
rect in principle.

ll Observatory, Flagstaff, A.T.:
1903 *March* 9.

Transits observed with the Durham Almucantar between 1901 *November* 23 *and* 1902 *December* 15.

By Prof. R. A. Sampson.

The Durham Almucantar has now been in use upon a settled plan for a sufficiently long time to show the quality of the work it can do. It seems of interest to publish the results without delay, although I do not doubt that a few years more of observation will improve them materially. I have therefore collected the observations made between 1901 November 23 and 1902 December 15, which have been taken and reduced upon a uniform plan, that may be looked upon as a final and approved one except in small points of detail.

The question which I proposed to solve with the almucantar was its title to compete with the finest transit circles in the fundamental work of finding star places, and in the course of this study to determine how to use it to the best advantage, and what were its weak and strong points. In fact, I proposed a thorough and extended revision and continuation of Mr. S. C. Chandler's original investigation, published in vol. xvii. of the *Harvard Annals*.

Striking as Mr. Chandler's work is, it is usually found that an inventor's methods are liable to improvement, and some of the modifications I have introduced are not immaterial.

Almost all the observations recorded below were taken by Mr. F. C. H. Carpenter. It was my original intention to share equally with him in the observations, and it is my hope to do so at some future time; but the earlier experimental work and the various changes made before the observing ran smoothly, with theoretical investigations, revision of reductions, and discussion of results absorbed the time I could spare so completely that I have been obliged for the present to give up the additional heavy tax that observing imposes.

Meanwhile it is perhaps as well to offer a completely homogeneous group by one observer as a specimen of what the instrument will do.

§ 1. *The Durham Almucantar as at present used.*

A general description of the almucantar as set up at Durham was published in *Monthly Notices*, 1900 June (vol. lx. p. 572).

Without repeating these details I may say briefly that it is an instrument for taking transits, with horizontal wires, movable in azimuth, and clamped at the altitude of the pole. Its characteristic feature is that the movable parts are floated on a mercury bath, and it is in the first place assumed that after a disturbance such as arises from setting to a fresh azimuth, the telescope settles down to the same Z.D. as before. Each star

makes a transit east and a transit west of the meridian, cutting the spider lines obliquely at an angle equal to its own hour-angle; the azimuth at which any star transits is roughly computed for the purposes of setting; the hour-angle is rigorously computed from assumed data for the purpose of comparing these with the result of observation. The observations are exclusively time observations, and are taken with Professor Hough's printing chronograph described below. The theory of the instrument and the method of reducing and combining the observations are also given in full in subsequent sections. I will add only a description of some changes and additions made to the instrument since the description was published.

The original plate of lines for observing consisted of lines ruled upon a plate of glass: this was discarded after trial, and a plate carrying spider lines replaced it. There is one vertical line and twenty-seven horizontal ones. Twenty-five of these in five tallies of five lines each are designed for chronograph observations; the other two come in if there is occasion to observe with eye and ear. The chronograph lines are very close together, separated by 0·005 inch in the same tally, and by 0·01 inch between two tallies, which is about 14″ and 28″ upon the sky. It is desirable to have the lines as close as is found safe and convenient for observing in order to keep within a moderate distance of the centre of the field the transits of stars which cross the lines at a small angle. The wire intervals and their inclination to the horizon are discussed in detail below.

The original eye-piece was inserted in a socket fixed to the telescope tube. It was not possible to slide it, for it is essential that the telescope should not be touched after it has ceased to oscillate. A guard ring carried by an arm independent of the floating parts was provided to rest the eye against in order to prevent accidental disturbance. This was not satisfactory. The outer lines were crossed far from the centre of the field of the fixed eye-piece, and considerable coma was introduced into the images which ruined the observations.

I cleared away the fixed eye-piece and the guard ring, and replaced them by a sliding eye-piece carried by the same arm as formerly carried the guard ring. This eye-piece is therefore independent of the telescope. It worked at once with perfect success. It has adjusting screws to set it in its mean position over the centre of the system of spider lines, and the sliding motion can be made in any direction across the field so as to follow each star at its proper obliquity. After the telescope is set in azimuth, the direction of the slide is set to the proper angle by means of a roughly graduated circle.

When the observations are over, the eye-piece and its slide are withdrawn, and a cap put over the end of the telescope tube to protect the spider lines from injury.

All transits are taken with dark field and bright lines, illuminated by two minute electric lamps.

The telescope as shown in the published photograph is n guarded from wind, and this prevented observation on so nights otherwise fine. In the early months of 1902 an expe mental screen was tried with success, and in August t instrument was boxed in almost completely by a screen co structed by Messrs. T. Cooke & Sons. The frame of this scree is of iron and the panels of perforated zinc sheet which allow the free circulation of air, but breaks up the gusts which formerly set the instrument rocking. The framework of this screen is fastened to the trough and to the arm which carries the eye-piece; all the telescope, from eye end to object-glass, is covered in. The old dew-cap fixed to the O.G. cell is removed, and a hood attached to the screen which covers in this cell and carries a new dew-cap. This screen does its work successfully. Formerly a gust of air, impinging, I suppose, on the float or dew cap or eye-end would set the telescope rocking in Z.D. Now the only effect of a gust I can discover is a very slow motion between the small limits of azimuth allowed for clearance, and this probably has no sensible effect whatever in Z.D.

The screen is otherwise convenient, for there is plenty of space to spare within it, and it has been provided with a shelf on which is put a small accumulator for illuminating the wires.

No gas or oil lamp is used in the telescope room. The azimuth circle is read by small electric lamps from this accumulator, which also lights up a sidereal watch which hangs upon the frame of the wind screen.

The movable dome consists of almost the whole roof of the telescope room, which is run aside over the roof of a neighbouring room. When open the observing room consists of nothing more than four walls. Judging from the steady definition we get, I should say the circumstances are favourable for good observing.

§ 2. *Theory of the Individual Observation.*

An observation with the almucantar, as with most other instruments, yields an equation defining corrections to assumed data. Such an equation was given by Mr. Chandler, and the following treatment is not fundamentally different from his; but I believe it will be found more straightforward, as it develops the theory of all the corrections from a single original equation: it is also in some minute respects more exact.

Defining the colatitude circle as the horizontal small circle of almucantar which passes through the pole, call

ζ the true elevation of an object above the colatitude circle;

δ its true declination;

t its hour-angle, + West, − East;

φ the true latitude;

then we have the equation

$$\sin(\phi+\zeta)=\sin\phi\sin\delta+\cos\phi\cos\delta\cos t \quad \ldots \quad (1)$$

Further, let ϕ_o be the adopted latitude of the observatory, and let a table be computed giving t_o for every value of the argument δ_o from the equation

$$\sin\phi_o=\sin\phi_o\sin\delta_o+\cos\phi_o\cos\delta_o\cos t_o \quad \ldots \quad (2)$$

Then if δ_o be the adopted declination of the object, we write

$$\phi=\phi_o+\Delta\phi \qquad \delta=\delta_o+\Delta\delta$$

and $\Delta\phi$, $\Delta\delta$ will be so small that their squares may in all cases be neglected; then equation (1) may be written

$$\sin\phi_o+\cos\phi_o\sin(\zeta+\Delta\omega)-\sin\phi_o\,.\,2\sin^2\frac{\zeta+\Delta\phi}{2}$$
$$=\sin\phi_o\sin\delta_o+\Delta\phi\cos\phi_o\sin\delta_o+\Delta\delta\sin\phi_o\cos\delta_o$$
$$+(\cos\phi_o\cos\delta_o-\Delta\phi\sin\phi_o\cos\delta_o-\Delta\delta\cos\phi_o\sin\delta_o)\times$$
$$\left(\cos t_o-\sin t_o\sin(t-t_o)-\cos t_o\,.\,2\sin^2\frac{t-t_o}{2}\right)$$

where $\Delta\phi$, $\Delta\delta$ are supposed expressed in circular measure. In this it is plain that we may drop the terms $[\zeta,\sin(t-t_o)]\times[\Delta\phi,\Delta\delta]$, since their retention is equivalent to increasing by insensible amounts the coefficient of $\sin(t-t_o)$ or of ζ; further

coeff. of $\Delta\phi=\cos\phi_o\sin\delta_o-\sin\phi_o\cos\delta_o\cos t_o$
$$=(\sin\delta_o-\sin^2\phi_o)\sec\phi_o$$
„ „ $\Delta\delta=\sin\phi_o\cos\delta_o-\cos\phi_o\sin\delta_o\cos t_o=\cos\phi_o\cos t_o$

Hence the equation reads

$$\sin\zeta-\tan\phi_o\,.\,2\sin^2\frac{\zeta}{2}+(1-\sin\delta_o)\sec^2\phi_o\Delta\phi=\cos t_o\Delta\delta$$
$$-\cos\delta_o\sin t_o\sin(t-t_o)-\cos\delta_o\cos t_o\,.\,2\sin^2\frac{t-t_o}{2} \quad \ldots \quad (3)$$

Now if

α_o=assumed R.A. of object;

$\alpha=\alpha_o+\Delta\alpha$, the true R.A.;

θ =clock time of observation;

$\theta+\Delta\theta$=true time „ „

then we have

$$t=\theta+\Delta\theta-(\alpha_o+\Delta\alpha)$$

and the assumed sidereal time is

$$\theta_o = a_o + t_o$$

so that if O−C stands for *Observed Time minus Computed Time*

$$O-C = \theta - \theta_o$$

and
$$t - t_o = O-C + \Delta\theta - \Delta\alpha \quad \ldots \quad \ldots \quad (4)$$

Equations (3) and (4) are fundamental equations of the almucantar.

Now consider the equation

$$\zeta + (1-\sin\delta_o)\sec^2\varphi_o\Delta\phi = \cos t_o\Delta\delta - \cos\delta_o\sin t_o(O-C+\Delta\theta-\Delta\alpha) + R \quad \ldots \quad (5)$$

This is identical with (3) (4) provided

$$R = \zeta - \sin\zeta + \tan\varphi_o\, 2\sin^2\frac{\zeta}{2} + (t-t_o-\sin(t-t_o))\cos\delta_o\sin t_o - \cos\delta_o\cos t_o\,.\,2\sin^2\frac{t-t_o}{2} \quad \ldots \quad (6)$$

It is now necessary to define ζ with reference to the tallies of spider lines.

Let the true Z.D. of an object at its transit across the rth spider line, where this spider line meets the cross line perpendicular to it, be $\frac{\pi}{2}-(\phi+\zeta_r)$, and let γ_r be the inclination of this line to a true horizontal direction, reckoned positive when the west end is lowest, and b_r the distance from the intersection at which the transit takes place; then

$$\sin(\phi+\zeta) = \sin(\phi+\zeta_r)\cos b_r - \cos(\phi+\zeta_r)\sin b_r\sin\gamma_r$$

or with sufficient accuracy for all purposes

$$\sin\zeta - \tan\phi_o\, 2\sin^2\frac{\zeta}{2} = \sin\zeta_r - \tan\varphi_o\,.\,2\sin^2\frac{\zeta_r}{2} - \tfrac{1}{2}b_r^2\tan\phi_o - b_r\gamma_r$$

Moreover, if T be the hour-angle of transit across the central cross line

$$b_r = (t_r - T)\cos t_o\cos\delta_o;$$

hence the general equation for the rth wire is

$$\zeta_r + (1-\sin\delta_o)\sec^2\phi_o\Delta\phi = \cos t_o\Delta\delta - \cos\delta_o\sin t_o(O_r-C+\Delta\theta-\Delta\alpha) + R_r \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

where

$$R_r=\zeta_r-\sin\zeta_r+\tan\phi_0\,.\,2\sin^2\frac{\zeta_r}{2}-\tfrac{1}{2}(t_r-T)^2\cos^2 t_0\cos^2\delta_0\tan\phi_0$$
$$-\gamma_r(t_r-T)\cos\delta_0\cos t_0$$
$$+(t_r-t_0-\sin(t_r-t_0))\cos\delta_0\sin t_0-\cos\delta_0\cos t_0\,.\,2\sin^2\frac{t_r-t_0}{2}\ldots\quad(8)$$

Lastly, ζ_r determines the true Z.D. of the object at the time of observation, and for a fixed spider line ζ_r varies with the state of the atmosphere. We have the equation

$$\zeta_r+r=z_r$$

where r is the refraction, and $90^\circ-\phi-z_r$ the actual Z.D. of the rth spider line at its intersection with the cross line. Further neglecting differential refraction among the spider lines we may put

$$\zeta_r=z_r-r_r-\Delta r$$

where

r_r is the refraction for the mean state of atmosphere and the apparent Z.D. $90^\circ-\phi-z_r$;

$r_r+\Delta r$ is the same for the true state of atmosphere;

so that Δr is taken the same for all the lines, and r_r independent of the state of the atmosphere.

Then in equation (7) we must write z_r-r_r for ζ_r, and replace R_r by $S_r=R_r+\Delta r$. If, then, we tabulate S_r, and apply it as a correction, we shall have a correct linear equation between t_r-r_r, $\Delta\phi$, $\Delta\delta$, and $O_r-C+\Delta\theta-\Delta\alpha$. It is then required to reduce S_r to its simplest form.

Now it will suffice if S_r be correct to $0''\cdot01$, or in circular measure to 5×10^{-8}. Consider its members in turn, and in doing so it will be unnecessary to distinguish between ζ_r and the wire interval from the mean line.

(i) $\zeta_r-\sin\zeta_r$: if the breadth of the field is as much as $7'$, and the centre line is only a few seconds from the colatitude circle, ζ_r does not exceed $210''$, or, say, $\sin\zeta_r=0\cdot001$, which makes $\zeta_r-\sin\zeta_r=2\times10^{-10}$, which is negligible.

(ii) $+\tan\phi_0\,.\,2\sin^2\frac{\zeta_r}{2}$: or $\tan\phi_0\,.\,\frac{1}{2}\zeta_r^2$, which for lat. $54^\circ\,46'$ is $1\cdot4\times5\times10^{-7}$; hence it must be retained. If the complete tally of spider lines is observed it will yield a mere constant, which may be supposed united with z_r-r_r; but if the outer members of the tally are missed it may yield a sensible correction.

(iii) $-\frac{1}{2}(t_r-T)^2\cos^2 t_0\cos^2\delta_0\tan\phi_0$: if the telescope is carefully set in azimuth, the transit across the central cross line of the field may be taken as the same as the transit across the mean horizontal line of the tally, or $T=t_0$, and further we may take

$$t_r-t_0=+\zeta_r\sec\delta_0\operatorname{cosec}t_0$$

ence this correction may be w....

$$-\tfrac{1}{2}\,\zeta_r^2 \cot^2 t_o \tan \phi_o$$

(iv) $-\gamma_r\,(t_r - \mathrm{T})\cos\delta_o \cos t_o$: this becomes $-\gamma_r\,\zeta_r \cot t_o$.

(v) $\{t_r - t_o - \sin(t_r - t_o)\}\cos\delta_o \sin t_o$: this becomes $+\tfrac{1}{6}\zeta_r^3 \sec^2\delta$ cosec^2 t_o, and this is negligible provided sec δ_o cosec t_o does no exceed 16, that is, in lat. 54° 46′ for any star whose declinatio does not exceed 86°, or taking those near the limit of souther observation whose hour-angle does not fall below $0^h\ 15^m$.

(vi) $-\cos\delta_o \cos t_o \;.\; 2\sin^2\dfrac{t_r - t_o}{2}$: we may write for this

$$-\tfrac{1}{2}\,\zeta_r^2 \sec\delta_o \cos t_o \operatorname{cosec}^2 t_o$$

The second, third, and last of these terms may be collecte into the form

$$+\tfrac{1}{2}\,\zeta_r^2\,[+\tan\varphi_o - \cot^2 t_o \tan\varphi_o - \sec\delta_o \cos t_o \operatorname{cosec}^2 t_o]$$
$$= -\tfrac{1}{2}\,\zeta_r^2 \frac{\tan\phi_o}{\sin^2 t_o}\left[\cos 2t_o + \frac{1}{1+\sin\delta_o}\right]$$

Hence we have the equation

$$z_r - r_r + (1-\sin\delta_o)\sec^2\phi\Delta\phi$$
$$= \cos t_o \Delta\delta - \cos\delta_o \sin t_o\,(\mathrm{O}_r - \mathrm{C} + \Delta\theta - \Delta\alpha) + \mathrm{S}_r$$

where

$$\mathrm{S}_r = -\tfrac{1}{2}\zeta_r^2 \frac{\tan\phi_o}{\sin^2 t_o}\left[\cos 2t_o + \frac{1}{1+\sin\delta_o}\right]$$
$$-\gamma_r\,\zeta_r \cot t_o + \tfrac{1}{6}\zeta_r^3 \sin^2\delta_o \operatorname{cosec}^2 t_o + \Delta r \qquad \ldots$$

where in S_r, ζ_r may be treated as the wire interval from the m wire.

Now suppose that there are twenty-five wires, as in Durham instrument, and that all of these are observed ; def

$$\bar{z} = \tfrac{1}{25}\Sigma\,(z_r - r_r)$$
$$\mathrm{O} = \tfrac{1}{25}\Sigma\mathrm{O}_r$$

the equation becomes

$$\bar{z} + (1-\sin\delta_o)\sec^2\phi_o\,\Delta\phi$$
$$= \cos t_o\,\Delta\delta - \cos\delta_o \sin t_o\,(\mathrm{O} - \mathrm{C} + \Delta\theta - \Delta\alpha$$

where

$$\mathrm{S} = -\tfrac{1}{50}\Sigma\zeta^2 \frac{\tan\phi_o}{\sin^2 t_o}\left[\cos 2t_o + \frac{1}{1+\sin\delta_o}\right]$$
$$-\tfrac{1}{25}\Sigma\zeta_r\gamma_r \cot t_o + \tfrac{1}{150}\Sigma\zeta_r^3 \sec^2\delta_o \operatorname{cosec}^2 t_o + \ldots$$

Next suppose that p wires only were observed.

Take $O = \frac{1}{p}\Sigma_p O_r$ where Σ_p covers the actual observations; then

$$\frac{1}{p}\Sigma_p (z_r - r_r) = \frac{1}{p}\{25\,z - \Sigma_{25-p}(z_s - r_s)\}$$

where $_s$ refers to one of the dropped wires

$$= \bar{z} + \frac{1}{p}\{(25-p)\,\bar{z} - \Sigma_{25-p}(z_s - r)\}$$

$$= \bar{z} - \frac{1}{p} \times \{\text{sum of wire intervals for dropped wires}\}$$

Similarly $$\frac{1}{p}\Sigma_p \zeta_r^2 = \tfrac{1}{25}\Sigma_{25}\zeta_r^2 + \frac{25-p}{p}\cdot\tfrac{1}{25}\Sigma\zeta_r^2 - \frac{1}{p}\Sigma_{25-p}\zeta_s^2$$

or if $$\zeta_s^2 = k_s \times \tfrac{1}{25}\Sigma_{25}\zeta_r^2$$

$$\frac{1}{p}\Sigma_p \zeta_r^2 = \{1 + \frac{1}{p}[(25-p) - \Sigma_{25-p}k_s]\}\cdot\tfrac{1}{25}\Sigma_{25}\zeta_s^2.$$

Again, let $$\gamma_s\zeta_s = l_s \times \tfrac{1}{25}\Sigma_{25}\gamma_r\zeta_r$$

and $$\zeta_s^3 = m_s \times \tfrac{1}{25}\Sigma_{25}\zeta_r^3$$

and we have similar formulæ for the other two corrections.

The equation (10) will now be improved if we unite with $\bar{z}$ the mean part of the term $(1-\sin\bar{\delta}_o)\sec^2\phi_o\Delta\phi$ which diminishes to zero as δ_o increases up to $\frac{\pi}{2}$ but does not change sign. If we take an arbitrary fixed angle $\bar{\delta}$, and make the first term $\bar{z} + \{1-\sin\bar{\delta}\}\sec^2\phi_o\Delta\phi$ the second term becomes $(\sin\delta - \sin\bar{\delta}_o)\sec^2\phi_o\Delta\phi$, which changes sign at $\delta_o = \bar{\delta}$, and is therefore more readily separated from the first term in solving a group of equations.

Finally turn from circular measure to the measures proper to the different quantities, namely, seconds of time for O, C, $\Delta\theta$, $\Delta\alpha$, and seconds of arc for $\bar{z}$, $\Delta\varphi$, $\Delta\delta$; also write

$$z = \tfrac{1}{15}'(\bar{z}'' + \{1-\sin\delta\}\sec^2\phi_o\Delta\phi)$$

$$\Delta\theta' = \Delta_o\theta' + y$$

where $\Delta_o\theta$ is a round number adopted in advance of the dis-

cussion of the equation in order to clear out large quantities from O−C;

$$x = \tfrac{1}{10}\Delta\phi''$$

and

$$a = 1{\cdot}5 \cos \bar{\delta}_0 \sin t_0, \text{ taken always positive}$$
$$b = (\sin \bar{\delta} - \sin \bar{\delta}_0) \sec^2 \phi_0$$

then the standard equation for a single observation reads, the upper signs referring to a transit east, and lower to a transit west

$$\mp z + ay \mp bx + n = v \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

where $n = a(O' - C' + \Delta_0\theta') + S$

$v = a\Delta\alpha' \mp \tfrac{1}{10} \cos t_0 \Delta\delta''$

and

$$S = \pm\frac{1}{10p}\Sigma\{(25-p)\bar{z}'' - \Sigma_{25-p}(z_r'' - r_r'')\}$$
$$\mp\frac{\sin 1''}{500}\frac{\tan \phi_0}{\sin^2 t_0}\left(\cos 2t_0 + \frac{1}{1+\sin \bar{\delta}_0}\right) \times$$
$$\left[1 + \frac{1}{p}\{(25-p) - \Sigma k_s\}\right] \Sigma_{25}\zeta_r''^2$$
$$-\frac{\sin 1''}{250} \cot t_0 \left[1 + \frac{1}{p}\{(25-p) - \Sigma l_s\}\right] \Sigma_{25}\gamma_r''\zeta_r''$$
$$+\frac{(\sin 1'')^2}{1500} \sec^2 \delta_0 \operatorname{cosec}^2 t_0 \left[1 + \frac{1}{p}\{(25-p) - \Sigma m_s\}\right] \Sigma\zeta_r''^3$$
$$\pm\tfrac{1}{10}\Delta r'' \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

It is necessary to tabulate in the book which gives t_0 with argument δ_0 the quantities a, b, and the different parts of S (excepting $\frac{1}{10}\Delta r$). The first part of S is the correction for dropped wires; the second is for the curvature of the wires, that is, their departure from small circles of constant Z.D.; the third is for the inclination of the wires; the fourth for the curvature of the path of the star.

The angle $\bar{\delta}$ is arbitrary. It would be best to take it so as to divide into two portions of equal area the whole of the sky which comes into view or

$$\sin \bar{\delta} = \sin^2 \phi_0$$

for $\phi_0 = 54° 46'$, this gives $\bar{\delta} = 41° 52'$. In my actual work the angle used has been $\bar{\delta} = 52° 2'$, which is not so good; but I have not judged that the difference was great enough to call for the recalculation of the quantities b and all that depend on them.

§ 3. *Theory of the Combination of Observations.*

The foregoing equation differs slightly in the values of the small corrections and substantially in form from that adopted by Mr. Chandler (*Harvard Annals*, xvii., ch. ii., equation (7)). The choice of form has been determined by two considerations, these being, first, economy of labour in applying the corrections; and, second, the form which expresses correctly the relative weights in determining the different constants of observations taken at different declinations. In the transit circle it is usual to treat observations of equal weight in determining clock correction up to a chosen declination, beyond which they are not used for this purpose at all, and Mr. Chandler followed a similar plan for the almucantar. But it is clear that for the almucantar it would be far nearer the truth to treat all observations wherever taken as of equal weight in determining the constant z the slow motion of the stars of higher declination being compensated by the obliquity of the transits of the lower ones; and that such a treatment is not only plausible but very near the truth is shown by Mr. Chandler's investigation of the errors in Z.D., as determined by groups of stars of different declinations He gives the following table derived from his own results p. 81):—

Probable Accidental Error of a Single Observation in Zenith Distance.

Mean δ.	Range in δ.	Prob. Error.	Mean δ.	Range in δ.	Prob. Error.
° 85	° 89 – 81	± 0″35	° 62	° 62 – 60	± 0″43
78	80 – 77	0·32	55	59 – 46	0·35
75	76 – 74	0·47	38	43 – 33	0·43
72	74 – 71	0·36	23	27 – 20	0·44
70	70 – 67	0·35	15	19 – 11	0·47
66	67 – 63	0·36	0	7 – – 5	0·46

And with this table he gives reasons to believe that the increase of probable error at mean declination 75° and below 38° is due to causes which for my purpose are irrelevant. Relying upon these results, I have thrown the fundamental equation into a form which gives to z the same coefficient for all declinations.

To obtain information about an individual star from the fundamental equation (11) it is first necessary to know the instrumental constants z, y, x by means of a combination of all the observations. The best way to do this is to take well-determined stars, assume v to be zero, and combine the resulting

equations by Least Squares. For the almucantar this can be done with very little labour, and here the full advantage is realised of deriving all the unknowns from a single type of equation in place of the many different kinds of observation upon which the transit circle depends. It is only necessary to tabulate with argument δ_0 in the book already used for finding t_0, a, b, the values of a^2, ab, b^2, s, as, bs, where $s=-1+a-b$ for transits east, and $+1+a+b$ for transits west. Then when n is determined we have only to form na, nb, ns by the help of Crelle's Tables. If this is the first time the powerful rules of Least Squares have been employed in transit work, I think it may claim to be a material advance, and, besides being theoretically the best, the method has been found a thoroughly practical one in use. The freedom from hesitation as to which observations to use for this or that constant, and how to combine them and the automatic checks upon accuracy which the method supplies, more than make up for the labour it involves.

When x, y, z have been determined and substituted in the equation of condition (11), the residual v is offered as a correction to the star's assumed place, viz. $v=a\Delta a^s \mp \frac{1}{10} \cos t_0 \Delta\delta$. The value of v, together with the constant $a=1{\cdot}5 \cos\delta_0 \sin t_0$, and $\frac{1}{10}\cos t_0$, must be posted to the proper place in the star ledger. But before doing this I have latterly made another step to see whether there is any indication of a progressive change in the value of z in the course of the night. Adopting the values of x, y given by the solution of the normal equations, I have substituted these in the equations of condition, supposing $v=0$, and have ascertained what value of z is required to satisfy the equation of condition. These values of z I have sometimes charted, and from their lie upon the chart have estimated what change has taken place in z, proportionately with the time, or, better, taking the value given by solution of the normal equations as that which corresponds to the mean of the times of observation, I have taken also the mean of the z's preceding this time and also of those following it, and from these have derived the rate of change. Sometimes there is a well-marked indication of change and sometimes there is none. Where any change has been recognised, I compute the corresponding value of z for each observation, and finally adopt v from the equation

$$v=\mp(z_a-z_i)$$

where

$$z_a=z+(t-t_0)\Delta z$$

being the adopted value of z, allowing for the change Δz, and

$$\mp z_i+ay\mp bx+n=0$$

or z_i is the value of z indicated by the individual equation treated as correct.

It will be seen that my method determines the latitude cor-tion $\Delta\phi''=10x$ from each night's observations. The solution uld be simplified and abridged materially if $\Delta\phi$ were treated as own, as Mr. Chandler has done; but there are several reasons t determined me to retain $\Delta\phi$ as an unknown in every set of ervations from which it could reasonably be derived; first is variable, and if it is not treated as an unknown its varia-s will vitiate v systematically; again, to compare the values ϕ obtained night by night will give a better immediate test any other of how near the truth the solution lies. The rvations recorded below were not specially directed towards ing $\Delta\phi$; had that been so, as great a range as possible in declina- would have been observed, so as to make Σb^2 large while Σb, were small; but there are special difficulties in connection working with the limiting declinations that determined me ostpone any such investigation till I was satisfied with the k of the instrument at declinations not complicated by these culties. Hence the individual determinations of $\Delta\phi$ are of reat weight, and possess peculiarities to which I shall draw ntion in the proper place.

Observations of the same star must be made both east and t before we can determine the corrections of its coordinates. se observations may be separated by a considerable interval, it is not practicable to get observations of many stars and west on the same night. As a rule, if the observing is e at the same time of day, say from 9 P.M. to midnight, in time a given star will transit as an east star for a space of y-five days, and afterwards, at an interval which increases the declination from zero to half the year, as a west star for y-five days. In these periods a number of east observations a number of west observations must be secured if any ections to catalogue places are to be derived.

It is of the essence of the foregoing method of solution that residuals for all stars, whether their declinations are high or , are presumably of equal magnitude. There is no more reason xpect a large residual from *Polaris* than from *Pollux*. Hence measures of the error in the two coordinates are given by the procals of the two coefficients in the equation

$$v = 1{\cdot}5 \cos\delta_0 \sin t_0 \Delta\alpha^s \mp \tfrac{1}{15} \cos t_0 \Delta\delta''$$

is in low declination the almucantar determines declination er than R.A., and in high declinations reverses this, and question of the almucantar *versus* the transit circle may be briefly: How small can the probable error of v be made, what range of declination can we establish over which a ain error in v will not be outweighed by the factors $1{\cdot}5 \sin t_0$, os t_0, which do not figure in the theory of coordinates found he transit circle?

§ 4. *Reductions and other Calculations for the Almucantar as used at Durham.*

In judging the convenience of a method designed for permanent use no great account need be taken, as a rule, of labour spent on calculations which can be done once for all and fixed in the form of an auxiliary table. For the almucantar such an auxiliary table must give with argument δ_o the quantities t_o, a, b, &c. in the form most convenient for use. Assuming the adopted latitude ϕ_o is correct within a second, or even within several seconds, this will never need to be remade, and hence trouble will be well spent that makes it more convenient. The following is a specimen of the table I use: From $\delta_o = 25°$ to $\delta_o = 90°$ the left-hand page shows the value of t_o for every minute of arc, with D, which is the change in t_o for a single second, computed for latitude $\phi_o = 54° 46' 6''{\cdot}2$; thus:

No. 1. *Hour Angle and Constants Book.*

$\delta_o = 38°$ $\qquad$ $t_o = 3^h\ 5^m \cdots 3^h\ 10^m$

	t_o	D		t_o	D		t_o	D
′	m s		′	m s		′	m s	
0	5 17·449	0807	20	6 53·930	0801	40	8 29·507	0793
1	22·297	0808	21	58·730	0800	41	34·263	0792
2	27·138	0807	22	7 3·527	0800	42	39·015	0792
3	31·979	0807	23	8·322	0799	43	43·765	0792
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Thus, if, for example, the apparent declination of a star at date as derived from the catalogue be $38° 41' 39''{\cdot}4$, using Crelle's Tables we apply $39''{\cdot}4 \times {\cdot}0792$ to $3^h\ 8^m\ 34^s{\cdot}263$, giving $t_o = 3^h\ 8^m\ 37^s{\cdot}383$ as the computed hour-angle of its transit.

Between $\delta_o = 25°$ and $\delta_o = 21°$ it is necessary to take account of second differences and of third differences between $\delta_o = 21°$ and $\delta_o = 19°\ 32'$, which is the limit for latitude $54° 46'$, and the table is arranged accordingly.

On the right-hand page of the same opening stand all the subsidiary quantities that will be wanted at any stage of the work, namely A, the azimuth setting required to find the star, a, b, the coefficients defined in § 2, viz. $a = 1{\cdot}5 \cos \delta_o \sin t_o$, $b = (\sin \bar{\delta} - \sin \delta_o) \sec^2 \phi_o$, in which $\bar{\delta}$ has been taken at $52°\ 2'$, a^2, ab, b^2, s, as, bs, both east and west, for forming normal equations, $\cos t_o$ which is required in the star ledger as the coefficient of $\frac{1}{15}\Delta\delta''$, and the correction for the curvature of the wires, being the second member of the correction S of § 2,

pting the factor referring to dropped wires, which depends
i the determination of wire intervals given later. The third
iber of S, being the correction for inclination of the wires,
ld also be added ; but till now I have not made the observa-
i or discussions necessary for finding it, and have treated it
ero. The fourth member I have also neglected, since,
pting for the original determination of wire intervals which
i reduced by Mr. Chandler's method, I have taken no transits
hich it would be sensible.
The upper sign refers to the transit east and the lower sign
ansit west ; the small numbers are differences for 10′.

No. 1. *Hour Angle and Constants Book.*

$\delta_0 = 38°$.

	0′		10′		20′		30′		40′		50′		60′
	8° 1′ 15	24	81° 29	24	81° 53	24	82° 17	24	82° 41	23	83° 4	24	83° 28
	·855	1	·856	1	·857	1	·858	0	·858	1	·859	1	·860
	·519	7	·512	7	·505	6	·499	7	·492	7	·485	7	·478
	·731	2	·733	1	·734	2	·736	0	·736	2	·738	2	·740
	·444	6	·438	5	·433	5	·428	6	·422	5	·417	6	·411
	·269	7	·262	7	·255	6	·249	7	·242	7	·235	7	·228
	·664	8	·656	8	·648	7	·641	7	·634	8	·626	8	·618
	·568	7	·561	5	·556	6	·550	6	·544	6	·538	7	·531
	·344	8	·336	9	·327	7	·320	8	·312	9	·303	8	·295
	2·374	6	2·368	6	2·362	5	2·357	7	2·350	6	2·344	6	2·338
	2·030	3	2·027	3	2·024	2	2·022	6	2·016	2	2·014	3	2·011
	1·232	20	1·212	19	1·193	17	1·176	20	1·156	19	1·137	20	1·117
	·691	3	·688	2	·686	3	·683	2	·681	3	·678	3	·675
∓	·007		·007		·007		·007		·007		·007		·006

All the interpolations can be done at sight from this table
the greatest ease ; the differences never became large except-
or A, which requires more detailed tabulation below $\delta_0 = 23°$.
We must next make a setting book, showing the azimuth and
sidereal time at which each star in the observing list makes
ransit. My observing list consists at present of all stars in
Nautical Almanac and Berlin *Astronomisches Jahrbuch*, with
nations exceeding $+19° 35'$. The hour of its transit is
, east, and $a_0 + t_0$ west, where a_0 is its R.A. taken from the
ogue. This is entered to the nearest minute of time. Along
it is entered the azimuth, to which the telescope must be

set (A). The column B gives the reading on a second vernier 90° from A, which it is more convenient to read in some positions of the instrument. To avoid errors of setting, transits west are entered in this book in red ink (below with an asterisk); the whole is arranged in a table in order of time. Thus, for example, at sidereal time 19^h, we have the following :—

No. 2. *Setting Book*, 1902.

19^h.

Name.	Mag.	R.A.	θ.	A.	B.
		h m	h m	° ′	
43 Cephei ...	4·3	0 55	19 8	172 37	
*ζ Herc.	3·1	16 38	19 9	65 1	24 59
Groomb. 2164 B.J.	5·8	14 49	19 19	126 6	36 6
*110 Herc. B.J.	4·0	18 41	19 24	17 17	
21 Cass. B.J.	6·0	0 39	19 24	152 54	
*ε Herc.	4·0	16 57	19 24	62 59	27 1
⋮	⋮	⋮	⋮	⋮	⋮

After a few years' use this book will require revision, since the tabulated azimuths will be a little out of truth owing to precessional changes in declination.

It is inadvisable to observe at less intervals than about $2\frac{1}{2}$ clear minutes. Hence we must choose between 43 *Cephei* and ζ *Herculis*, for example. I have aimed at getting a considerable number of observations of each star, and in place of observing these two stars on alternate nights I have for the present observed the latter exclusively. But since it is necessary to get transits east and west in order to derive corrections to the two coordinates, it is occasionally advisable to observe stars on alternate nights which come at nearly the same time, as 21 *Cassiopeiæ* and ε *Herculis* in the above list, in order not to sacrifice the observations made in the contrary phase. These disabilities, as far as they can be so called, are not peculiar to the almucantar, but present themselves also in the transit circle.

All the observer enters in his note book is the name of the star, its R.A., and the catalogue (*N.A.* or *B.J.*) from which it is derived.

The stars transit obliquely, each cutting the wires at an angle equal to its own hour-angle, and it is necessary after the telescope is set in azimuth to set the slide of the eye-piece so as to cross the wires at the same angle. This is done by help of a small table or chart hanging in the observing room, showing the hour-angle for any azimuth.

The third book required is the reduction book, in which the quantities n of equation (11), § 2 are derived from the observations. Below is a specimen of this book.

No. 3. *Reduction Book.*

Observer: C. *Date:* 1902 *Nov.* 17.

	No. of Star.	1	2	3
	Name	η Pegasi W.	ξ Persei E., B.J.	β Pegasi W., B.J.
	Notes	2	2	2
	a_0	$22^h\ 38^m$	$3^h\ 53^m$	$22^h\ 59^m$
	δ_0	29° 43′ 6″·0	35° 30′ 40″·3	27° 33′ 38″·1
		h m s	h m s	h m s
1	Obsd. Mean ...	0 57 25·536	1 0 0·607	1 2 44·621
2	Corrn. Chron. ...	−·042	−·052	−·043
3	Corrn. o^h S.T. ...	−·004	−·004	−·004
4	Compt. a ...	1 21 32·130	20 7 18·090	1 0 55·065
5	E t_0 ...	2 18 47·543	2 52 42·293	2 3 28·010
6	E + D$\Delta\delta$ ...	+·665	+3·518	+4·789
7	W. Compt. Do....	21 44 11·792		21 56 27·201
8	Personality ...			
11	Sum = O−C ...	+9·412	+4·452	+6·840
12	$\Delta_0\theta$	−5·750	−5·750	−5·750
13	(11)+(12) ...	+3·662	−1·298	+1·090
14	(13) × a ...	+2·714	−1·085	+·744
15	Curv. and Incl....	+·021	−·010	+·030
16	Refraction ...	−·112	+·112	−·112
17	Dropped Wires	(24, 25) −1·881		
20	Sum = s ...	+0·742	−0·983	+0·662
21	v	+·09	+·01	−·02

In this form, the space *Notes* refers to the seeing 1 to 5, 1 being perfect. a_0 is a rough value, δ_0 is the exact apparent declination at date as given by interpolation from the catalogue.

1 and 2. *Obs. Mean* and *Corr. Chron.* are sufficiently explained below in describing the chronograph.

3. *Corr.* o^h S.T. is the allowance for clock rate, entered after rough examination has shown what is the approximate clock error.

4. This is the complement of the apparent R.A. at date derived from the catalogue.

5 and 6. These together give the hour-angle corresponding

to the value of δ_0 above derived from the book No. 1, where it is computed.

7. For a star transiting west, after writing down 5 and 6, we strike them through and write instead the complement of their sum.

8. Personality. No allowance has been made so far under this head.

The sum of the quantities 1, 2, 3, 4, with 5, 6, or with 7, gives O−C; the greater part of this is usually clock error; in the present case the clock correction is estimated at sight to be $-5^s{\cdot}750$, and this quantity ($\Delta_0\theta$) applied to each sum. The sum $O-C+\Delta_0\theta$ is now multiplied by a, taken from the book No. 1, and the different terms of S are applied to it.

Barometer and thermometer for refraction are taken at the beginning and end of the series of observations, and Δr, the correction to be applied to the mean refraction, is computed from the table given with the Greenwich observations for 1898: this is done in a moment, as the zenith distance is always the same. From this the hourly rate of change of refraction is calculated: it is assumed to be uniform, and indeed it appears to vary very little from night to night, coming out repeatedly at about $+0''{\cdot}1$ per hour. In accordance with the formula for S § 2, (12), refraction is applied with its natural sign east, and reversed sign west.

17. The correction for dropped wires is taken without multiplication by any factor from the table of wire intervals.

20. The sum 14, 15, 16, 17 is the quantity n, the absolute term of the equation of condition, and is carried to the book No. 4, where these equations are solved. The residual after their solution, v, is carried back and entered in (21) as well as in the star ledger.

In the next book, No. 4, the equations derived from the observations are collected in the following form. The numbers inclosed in brackets are entered after the solution is made and in the original are written in red.

No. 4. *Solution*

Date: 1902 November 17.

No.	±1.	a.	±b.	s.	n.	v.	tot.
1	+1	+·741	+·880	+2·621	+·742		
	(−·744)	(+·168)	(−·077)			(+·089)	(− 8″·33)
2	−1	+·836	−·624	− ·788	−·983		
	(+·745)	(+·190)	(+·055)			(+·007)	(−7·38)
3	+1	+·683	+·979	+2·662	+·662		
	(−·746)	(+·155)	(−·086)			(−·015)	(−7·31)
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

In filling up this table a, b, s, aa, ab, bb, as, bs, are read out of the book No. 1 with argument δ_0. n is then carried in from the book No. 3, as we have just seen; an, bn, sn are formed by help of Crelle's Tables, and the normal equations are then complete when the columns are added, and this is done very rapidly with the Comptometer, especially if positive and negative quantities are separated by setting the former a little to the left and the latter a little to the right in the columns. In taking these sums we must remember to affect a, b with the sign of unity as it stands in the first column, for we are seeking not Σa, but $\Sigma(\pm 1 \times a)$.

On the same page is a ruled form for solving the normal equations; the solution gave in this case $x = -\cdot0879$, $y = +\cdot2266$, $z = -\cdot7616$, indicating $\Delta\phi = -0''\cdot879$, the clock correction at 0^h S.T. $= -5^s\cdot750 + 0^s\cdot227 = -5^s\cdot523$, (the quantity $-5^s\cdot750$ being what was empirically applied in book No. 3 in order to diminish the residuals), and the mean collimation constant $= -7''\cdot616$.

I now take the constant $-\cdot0879$ and multiply it by the coefficients b, and similarly $+\cdot227$ is multiplied by the coefficients a: these give the numbers inclosed in brackets. Then in order that the first equation should be exact, giving zero residual we must have $z = -(\cdot742 + \cdot168 - \cdot077) = -\cdot833$, so that the first equation alone indicates a collimation constant $-8''\cdot33$. Similarly the second equation alone indicates $-7''\cdot38$, and the third $-7''\cdot31$, and if all the equations are so treated, and we collect the indications of the first half (11 observations) and of the second half (10 observations), we find the means:—at $1^h\ 26^m$, $10z = -7''\cdot52$; at $2^h\ 41^m$, $10z = -7''\cdot72$; while the general solution gave at $2^h\ 3^m$, $10z = -7''\cdot62$; hence the rate of change per hour $10\Delta z = -0''\cdot16$, and I adopt for this night $10z = -7''\cdot62 - 0''\cdot16(\theta - 2^h\ 3^m)$. The values given by this formula are entered in the second column, and the residuals are the differences between the numbers z as standing in the second

Book.

Observer: C.

aa.	$\pm ab$.	bb.	as.	bs.	an.	bn.	sn.
+·549	+·652	+·774	+1·943	+2·305	+·550	+·653	+1·945
+·699	−·522	+·389	−·659	+·490	−·822	+·613	+·775
+·466	+·669	+·959	+1·818	+2·608	+·452	+·648	+1·762
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

and in the eighth columns with the proper sign. Finally the instrumental constants, with a note of the mean residual, are collected at the end of this book, and the residuals are posted to the individual stars in the star ledger.

The star ledger is the last of the books (No. 5). There is little to remark about it ; a single entry will explain it.

38	
α Aurigæ.	
$5^h\ 9^m\ 26^s{\cdot}888$	
$45°\ 53'\ 55''{\cdot}02$	
·855	∓·574
1901	
* Dec. 27	−·04
1902	
Oct. 20	−·04
,, 30	·00
Nov. 7	−·02
,, 10	+·02
,, 12	−·08
,, 17	+·01
Dec. 15	(+·05)
1902	
Feb. 28	−·11
* March 10	−·05
* April 17	−·11

The place of the star is the mean place for the year 1902 taken from the catalogue, in this case the *Nautical Almanac*. The numbers that follow are the coefficients multiplying $\Delta\alpha^s$ and $\frac{1}{10}\Delta\delta''$ in the expression which makes up the residual v, the second member being negative east, positive west. Then follow the separate residuals, the first set representing transits east, the second transits west. The asterisk indicates that I was observing ; the others are Mr. Carpenter's. The bracket round the observations of December 15 indicates that the whole set was condemned, as there was something abnormal in 10z as indicated from the separate observations. Taking the means of what was observed, and omitting December 15, the outcome of these observations is the two equations

$$\cdot 855\ \Delta\alpha^s - \cdot 0574\ \Delta\delta'' = -\cdot 021$$
$$\cdot 855\ \Delta\alpha^s + \cdot 0574\ \Delta\delta'' = -\cdot 090$$

or

$$\Delta\alpha^s = -0^s{\cdot}065\quad \Delta\delta = -0''{\cdot}60$$

§ 5. *The Printing Chronograph.*

The transits recorded below, excepting those of close circumpolars taken for determining wire intervals, were taken with the printing chronograph designed by Professor G. W. Hough, of Dearborn Observatory. It was made by a Chicago firm, but its success in working is, I believe, entirely due to the pains Professor Hough most kindly took in examining and correcting the essential parts before it was sent to me.

The instrument is the same, except for minor details, as described by Professor Hough in the Annual Report of the Chicago Astronomical Society for 1885 and 1886; but as I believe there is no other example of it outside the United States, and it is not nearly so well known as it should be, I add sufficient description to make the following results intelligible.

There are three wheels revolving side by side, with type cut in relief upon their rims. The first revolves once in an hour, and bears the numbers 0 to 59 upon it for the minutes; the second revolves once a minute and also bears the numbers 0 to 59 for the seconds: these two move forward by steps upon a signal sent each second by the sidereal clock. The third wheel revolves once a second: it is driven by a different train of clockwork; it does not move by steps, but rotates continuously, and can be regulated to run faster or slower. If it is running truly with the sidereal clock the clock signal does not affect its running; if it is running fast it is detained at a certain point of its revolution until the signal comes and lifts an arm which it cannot pass; it is set to run a little fast, so that the signal acts as a slight check upon its going. If then its running should fluctuate and fall slow, the absence of this check acts so as to make it recover; but it must never be allowed to fall seriously slow, or the signal will fail to exercise any true check at all. This wheel has the even numbers 0 to 98 cut upon its rim, so that an odd hundredth of a second is indicated by the neighbouring even ones. Above these wheels an inked ribbon is moved slowly forward, and above this a strip of paper about two inches broad is drawn from a roller as required; above this, again, are three small hammers which, on a signal from the observer, strike the paper against the revolving wheels, and thus print the time of his observation. These hammers, if moved down slowly, stand clear above the type wheels, but they are carried by long arms flexible downwards, so that when suddenly depressed they fly below their equilibrium position and strike the type wheels without stopping them. The paper is moved forward by a third train of clockwork by a contrivance which acts automatically after a signal is sent, or may be actuated independently so as to leave any desired space between successive records.

There is also a key which when held down causes the clock signal to act also as a printing signal, so that for as long as

desired the chronograph will print the times that correspond to successive clock signals, and thus show if it is running fast or slow.

The minute wheel is first set in agreement with the clock, and the second signals set going when the clock and the second wheel are also in agreement. The key, which I call the clock key, viz. that which causes the clock to print when it signals, is then held down for a few seconds, and the record examined. It is satisfactory if it prints, say, $+0^s{\cdot}03$ or thereabouts fast of the clock, assuming the wheel is so set on its axle as to print 0·00 when the check is just not acting. Then going to the telescope the observer holds in his hand a piece leading from the chronograph and bearing three keys. About fifteen seconds before the star begins its transit he holds down for three or four seconds the clock key, and thus gets a record of the rate at which the chronograph is at that instant running; he then puts down the spacing key, moving the paper forward about an inch, then takes the transits over the twenty-five wires in the usual way with the recording key, puts in another space, holds down the clock key for another three or four seconds, and finally puts in enough space to allow the paper to be afterwards cut in sections and the necessary particulars of each star inserted. It is verified at the beginning and end of the night's observations, and from time to time in the middle, that the chronograph is printing correctly in agreement with the clock, and has not by any accident dropped a second—a thing which can only happen if the clock signal fails to pass.

Then to reduce the observation so made the stars are identified, their names written in, the paper cut in strips one to each star, missing wires marked, and any chance obscurity of printing cleared, and lastly the mean of all the wires observed is carried to the transit book, together with the mean, with sign reversed, of the record given by the clock key. The former corrected by the latter is taken as the time of transit. There is no time spent in deciphering the record as in the common drum chronograph, and there is no necessity to transcribe into the book the details of the transit. The slips containing the transits of each night, together with the checks upon the agreement of clock and chronograph, are fastened in a bundle and kept. The additions, which with twenty-five wires are very heavy, are invariably done with Felt and Tarrant's Comptometer, an invaluable adding arithmometer.

The fluctuations in the running of the chronograph in the course of one night are very small, as may be seen from the amounts allowed in correction of the transits of successive stars; for example, on 1902 Nov. 7, between $0^h\ 23^m$ and $1^h\ 54^m$ for the fifteen stars observed that night, these amounts were $-0^s{\cdot}038$, $-0^s{\cdot}042$, $-0^s{\cdot}026$, $-0^s{\cdot}036$, $-0^s{\cdot}024$, $-0^s{\cdot}022$, $0^s{\cdot}000$, $-0^s{\cdot}010$, $-0^s{\cdot}006$, $-0^s{\cdot}015$, $-0^s{\cdot}032$, $-0^s{\cdot}028$, $-0^s{\cdot}018$, $-0^s{\cdot}025$, $-0^s{\cdot}005$; on November 10, between $0^h\ 29^m$ and $1^h\ 54^m$, the amounts were $-0^s{\cdot}073$, $-0^s{\cdot}060$, $-0^s{\cdot}044$, $-0^s{\cdot}048$, $-0^s{\cdot}048$,

$-0^s{\cdot}046$, $-0^s{\cdot}044$, $-0^s{\cdot}041$, $-0^s{\cdot}040$, $-0^s{\cdot}020$, $-0^s{\cdot}023$, $-0^s{\cdot}024$, $-0^s{\cdot}042$, $-0^s{\cdot}040$, $-0^s{\cdot}038$; and these are fairly representative of the running. It seems fair to assume that any irregularity in the running as between two stars on the same night, or between the deduced clock corrections on different nights, is absolutely eliminated.

It remains to be examined what is the probable error of printing a correctly sent signal. Professor Hough's manner of testing this was to cause a mean-time clock to send a signal to the recording circuit once a minute ; by this device the printing was tested at every fraction of a second in turn.

Testing my chronograph thus before it was sent from America, Professor Hough found the probable error of a single print was $\pm 0^s{\cdot}013$. I repeated this test when I received the instrument, attaching a roughly made signal apparatus to a clock whose rate was for the time being made approximately mean-time rate. On 1901 October 31 this clock sending signals once a minute lost in 27 minutes $4^s{\cdot}44$ on the sidereal clock, or at the rate of $0^s{\cdot}165$ per minute. Using this rate the difference between the recorded and computed times of the signals were (in the sense Recorded—Computed), $-0^s{\cdot}03$, $+0^s{\cdot}01$, $-0^s{\cdot}02$, $-0^s{\cdot}03$, $0^s{\cdot}00$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $+0^s{\cdot}02$, $+0^s{\cdot}03$, $-0^s{\cdot}01$, $+0^s{\cdot}01$, $-0^s{\cdot}01$, $+0^s{\cdot}04$, $-0^s{\cdot}01$, $0^s{\cdot}00$, $+0^s{\cdot}01$, $0^s{\cdot}00$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $-0^s{\cdot}02$, $-0^s{\cdot}02$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, which gives as the probable error of a single print $\pm 0^s{\cdot}011$. It must be remembered that this error is not due to the chronograph alone ; if e is that of the chronograph and e' that of the signal apparatus, the amount above is equal to $(e^2+e'^2)^{\frac{1}{2}}$, and in this case the signal apparatus was very far from perfect. It is therefore safe to conclude that the probable error proper to the chronograph is barely sensible in amount, and does not reach $\pm 0^s{\cdot}010$.

§ 6. *The Wire Intervals and other Details of the Observations*

The plate at the principal focus of the object-glass carries one vertical and twenty-seven horizontal spider lines ; the horizontal lines I number 0 to 26, starting with that of greatest Z.D., that is, the line which an east star transits first. These lines are grouped in five tallies of five lines each, with two outside lines, 0 and 26 ; the lines 0 and 26 are used only for eye and ear observations (should there be occasion to take such), and the group of wires 0, 1, 7, 13, 19, 25, 26 are approximately equally spaced.

The interval between different tallies is roughly 30″, or 0·01 inch, and between successive lines of the same tally 15″, or 0·005 inch.

The intervals of these lines from their mean as at present adopted were found from twenty-seven transits of close circumpolar stars taken by eye and ear in the summer and autumn of 1901.

The transits observed were: B.A.C. 2320, two; λ *Ursæ Minoris*, three; B.A.C. 4165, six; B.A.C. 8213, six; 51 *Cephei*, two; δ *Ursæ Minoris*, three; α *Ursæ Minoris*, two. They were reduced by the method described by Mr. Chandler, and all observations were treated as of equal weight. The adopted results are as follows. The sign refers to a transit east, and must be reversed for a transit west.

Wire.	Interval from Mean.	Wire.	Interval from Mean.	Wire.	Interval from Mean.	Wire.	Interval from Mean.	Wire.	Interval from Mean.
	s		s		s		s		s
0	−332·52								
1	223·25	6	−125·60	11	−27·70	16	+ 68·21	21	+165·59
2	208·69	7	112·33	12	13·55	17	82·22	22	181·25
3	194·88	8	98·01	13	− 0·66	18	96·47	23	194·48
4	180·86	9	82·70	14	+14·34	19	113·36	24	208·85
5	−166·71	10	− 68·94	15	+26·85	20	+127·89	25	223·86
								26	+334·86

For the purposes of a comparison, which is explained below, I have taken out the errors of the six transits of B.A.C. 4165 from their own mean, and they are as below:—

Accidental Errors of Transits of B.A.C. 4165

Wire.	0	1	2	3	4	5	6	7	8	9	10	
1901.	s	s	s	s	s	s	s	s	s	s	s	
July 3	−0·1	+0·7	−0·1	+0·5	−0·2	−0·1	−0·5	−0·1	−0·3	+0·5	+0·2	+
4	+0·5	+0·5	0·0	+0·1	+0·2	+0·5	+0·5	+0·7	+0·7	+0·1	+0·1	−
15	+0·7	+1·0	+1·0	+0·2	+0·5	+0·5	+0·6	+0·5	+0·3	+0·4	+0·6	
20	+0·6	0·0	0·0	+0·5	+0·8	0·0	+0·5	0·0	+0·2	+0·3	0·0	
29	0·0	+0·2	+0·7	+0·3	+0·1	+0·6	−0·2	+0·2	+0·5	+0·1	+0·3	+
Aug. 2	−1·5	−2·2	−1·7	−1·6	−1·3	−1·3	−1·1	−1·3	−1·5	−1·4	−1·2	−

Probable erro

Accidental Errors

Wire.	1	2	3	4	5	6	7	8	9	10	
1902	s	s	s	s	s	s	s	s	s	s	
June 26	−0·2	−0·6	−0·7	+0·5	+0·1	−0·6	+0·7	−0·1	+0·2	0·0	−
,, 27	−0·4	+0·7	0·1	0·0	+0·2	−0·3	−0·4	+0·8	0·0	−0·9	
,, 30	−1·0	+0·7	+0·6	+0·2	+0·3	0·0	−0·4	+0·3	+0·2	−0·4	+
July 1	+0·3	−0·6	−0·1	−0·4	−0·7	+0·6	+0·8	−0·8	+0·2	+0·3	+
Aug. 23	+1·3	−0·1	+0·1	−0·4	+0·2	+0·1	−0·6	−0·4	−0·4	+0·9	−

Probable error

The column "p.e." is the probable error of a single observation, viz. the square root of the mean of the squares of the residuals opposite which it stands, multiplied by 0·6745.

Taking the whole of the observations (156) together, the probable error of a single observation is ±0″·437.

I have remarked above that the correction for inclination of the wires to the horizontal has been treated as zero. This was done because there was no material for finding it. But when a considerable body of transits has been taken, the details of these if analysed will show what correction should be allowed. At the same time such an analysis offers a searching test of the accuracy of the observations themselves, and of the justice of the assumption that stars of all declinations determine zenith distance, *i.e.* the collimation constant with equal precision. For these reasons I have determined the wire intervals separately from the detailed transits of several stars of different declinations, each of which had been observed five times or more on one side of the meridian. I will give the wire intervals determined as a mean from each star below, but will now schedule on the same plan as above the excess of the individual observed wire interval over the mean from all the transits of that star, and derive the probable error in zenith distance of a single transit at each declination.

ises, Observed minus Mean.

14	15	16	17	18	19	20	21	22	23	24	25	26	p.e.
″	″	″	″	″	″	″	″	″	″	″	″	″	″
0·5	0·0	+0·1	−0·1	0·0	+0·6	−0·4	−0·8	−0·4	−0·5	−0·4	0·0	−0·2	±0·25
0·3	0·0	+0·3	−0·2	+0·4	+0·1	−0·8	−0·8	0·0	−0·4	0·0	0·0	0·0	0·26
0·3	−0·2	−0·8	−0·6	−0·3	+0·4	−0·3	−0·4	+0·1	−0·8	0·0	+0·2	0·0	0·37
0·4	−0·3	0·0	+0·2	−0·1	−0·6	0·0	−0·5	−0·5	0·0	+0·4	−0·1	+0·1	0·23
0·8	+0·8	+0·2	+0·3	−0·1	−0·4	+0·3	+0·2	−1·1	−0·2	...	...	...	0·34
0·2	−0·2	+0·1	+0·4	+0·2	0·0	+1·1	+2·4	+2·0	+2·6	...	...	...	0·84

1 ±0″·437.

ises, Observed − Mean.

14	15	16	17	18	19	20	21	22	23	24	25	p.e.
″	″	″	″	″	″	″	″	″	″	″	″	″
0·6	−1·2	+0·7	−0·1	+0·2	−0·3	+0·3	+1·1	+0·3	...	...	...	±0·39
0·1	+1·3	+0·1	−0·5	0·0	+0·5	+0·2	+0·4	+0·2	−0·1	−0·4	−0·2	0·30
0·0	+0·5	+0·7	+1·0	−0·3	−0·3	−0·6	−1·0	−0·1	−0·7	−0·2	+0·2	0·37
0·2	+0·7	+0·6	−0·4	−0·1	+0·4	+0·3	−0·7	−0·4	+0·7	+0·5	0·0	0·34
0·6	−1·1	−1·9	...	...	...	...	...	...	...	...	...	0·53

1 ±0″·382.

ζ P

	1	2	3	4	5	6	7	8	9	10	1
1902											
Oct. 20	−0″.9	+0″.3	−1″.4	−0″.5	−1″.2	+0″.3	+0″.7	+0″.6	−1″.1	+0″.4	−1
,, 30	0″.0	−0″.6	+0″.3	0″.0	+0″.1	+0″.3	+1″.2	−0″.1	+0″.1	−0″.1	+0
Nov. 7	+0″.1	−0″.4	−0″.1	−0″.6	−0″.1	+0″.7	−0″.8	−0″.7	−0″.3	−0″.2	+0
,, 10	+0″.4	−0″.5	+0″.5	−0″.2	+0″.3	−0″.3	+0″.9	−0″.5	−0″.7	−0″.7	0
,, 12	−0″.6	+0″.2	+0″.8	+0″.4	+0″.2	−1″.6	−0″.7	+0″.3	+1″.3	0″.0	+0
,, 17	−0″.3	+1″.3	+0″.5	−0″.4	+0″.7	−0″.3	−0″.5	−0″.4	+0″.7	+0″.2	+0
Dec. 15	+1″.5	−0″.3	−0″.4	+1″.0	+0″.3	+0″.6	−0″.6	+0″.5	0″.0	+0″.4	+0

Probable error f

	1	2	3	4	5	6	7	8	9	10	1
1902											
Oct. 20	−0″.3	+0″.1	+1″.1	+0″.5	−0″.2	−0″.5	+0″.5	+0″.3	−0″.5	+0″.4	+0
,, 30	−1″.2	−0″.3	+0″.7	+0″.6	+0″.4	+0″.4	+0″.4	+0″.1	−1″.3	+0″.8	−0
Nov. 7	0″.0	+0″.9	−0″.8	−1″.7	+0″.9	+0″.1	−1″.1	−0″.5	+3″.3	+0″.1	−0
,, 10	0″.0	0″.0	−0″.2	−0″.2	+0″.7	−1″.0	−0″.4	+0″.3	+0″.4	−2″.2	−0
,, 17	+1″.5	−0″.1	−0″.2	+0″.2	−1″.4	+0″.2	−0″.4	−0″.6	0″.0	+0″.5	+0
,, 21	...	−0″.6	−0″.7	+0″.5	−0″.2	+0″.6	+0″.8	+0″.9	0″.0	+0″.4	+0

Probable error f

θ I

	1	2	3	4	5	6	7	8	9	10	1
1902											
Mar. 10	−0″.4	−0″.2	+0″.3	+0″.4	−0″.1	+0″.3	+0″.1	−0″.2	−0″.6	−0″.1	0
,, 17	−0″.1	+0″.3	+1″.4	−0″.4	−0″.2	−0″.1	−0″.5	+1″.7	−0″.5	+0″.6	−0
,, 22	+0″.1	−1″.2	+0″.1	+0″.9	+0″.3	+0″.8	−0″.2	−0″.7	+0″.2	0″.0	−0
April 2	+0″.5	+0″.6	−2″.5	−0″.4	−0″.5	−0″.9	+0″.4	−1″.2	+0″.6	+0″.3	−0
,, 4	−0″.1	+0″.6	+0″.9	−0″.4	+0″.6	0″.0	+0″.3	+0″.5	+0″.5	−0″.8	+1

Probable error fo

+31° 36′.

13	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
+0″·7	−0″·5	+0″·3	+0″·3	−0″·2	+0″·6	−0″·2	−0″·4	+1″·4	−0″·4	−0′·3	−0″·1	0″·0	±0″·6
−0·4	−1·4	0·0	−0·3	+0·7	+0·5	−1·1	−0·1	+0·5	+0·6	+1·0	+1·1	−0·5	0·4
+0·2	−0·2	+0·8	+0·6	+0·7	−0·1	+0·8	+0·3	−0·7	−1·0	+0·2	−0·7	−0·7	0·4
+0·2	+0·5	+0·8	+0·8	+0·7	−0·6	+1·5	+0·4	−0·7	−0·4	...	−0·4	−0·3	0·4
−0·7	+1·1	−1·2	−0·5	−0·7	−1·0	+0·2	0·0	0·0	+0·9	−1·1	+0·7	+1·2	0·5
+0·2	+0·6	−0·5	−0·6	−0·9	+0·3	−1·0	−0·2	+0·2	+0·6	+0·2	+0·3	+0·5	0·4
−0·2	−0·3	−0·4	−0·3	−0·2	+0·2	0·0	0·0	−0·6	−0·5	0·0	−1·2	−0·5	0·3

observation ±0″·475.

+41° 6′.

13	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
+0″·5	+0″·8	−0″·8	−0′·5	+0″·2	−0″·1	−0″·9	+0″·1	−1″·0	+1″·0	−0″·3	+0″·3	−0″·2	±0″·3
+0·8	−2·0	+1·3	+1·3	−0·9	−0·1	+1·3	−0·1	+1·0	−1·1	+0·6	+0·1	−0·3	0·5
−0·6	+1·1	+0·5	+1·0	−1·0	+0·9	−1·1	−0·4	+0·6	−0·9	−0·9	+0·3	−0·3	0·6
+0·4	−1·2	−0·6	+0·9	+1·1	+0·2	+0·5	+0·1	+0·2	0·0	0·0	+0·4	+0·7	0·4
−1·1	+0·6	−0·2	−0·8	+0·5	0·0	−0·2	+0·3	−0·6	+0·7	−0·2	−0·8	+0·6	0·4
0·0	+0·8	−0·4	−2·1	−0·2	−1·1	+0·2	0·0	0·0	+0·5	+0·5	−0·5	−0·5	0·4

observation ±0″·516

+52° 18′.

13	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
+0″·4	+0″·5	−0″·3	−0″·7	−0″·4	−0″·6	+0″·3	+0″·7	−0″·2	+1″·3	+0″·2	0″·0	0″·0	±0″·3
+0·3	+0·5	−0·3	+0·2	0·0	−0·6	−0·9	+0·1	+0·7	+0·8	+0·1	−0·5	−0·9	0·4
+0·1	−0·7	0·0	−0·5	+0·5	+0·8	+0·3	−0·9	−0·2	+0·6	+0·9	+0·1	−1·1	0·4
0·0	−0·4	+0·9	+1·1	0·0	−0·2	+1·2	+0·9	−0·5	−2·5	+0·1	+0·2	+1·4	0·6
−1·0	−0·1	−0·4	+0·1	−0·1	+0·1	−0·9	−0·7	0·0	0·0	−1·4	+0·3	+0·6	0·4

observation ±0″·475.

a Cep

	1	2	3	4	5	6	7	8	9	10	11
1902											
Oct. 20	−0.1	+0.4	−0.6	+0.4	+0.8	−0.1	−1.4	−0.9	+0.3	−1.8	+1.7 +
,, 30	−0.7	+0.5	+0.1	+1.7	−0.5	+0.6	+0.3	+0.6	−0.6	0.0	−0.3 +
Nov. 7	+0.6	+0.4	−0.6	+0.3	+1.2	−0.7	+0.4	+0.9	−0.3	+0.9	−0.1 −
,, 10	−0.1	−0.8	+1.3	−1.6	−1.0	+0.5	+0.8	−0.4	+1.1	0.0	−0.1 −
,, 17	0.0	−0.9	−0.1	−0.5	...	...	0.0	−1.3	−0.1	+2.0	−0.5 −
,, 21	+0.1	+0.4	−0.2	0.0	−0.5	−0.5	−0.1	+0.9	−0.1	−1.1	−0.6 −

Probable error for a

ε Dra

	1	2	3	4	5	6	7	8	9	10	11
1902											
Oct. 20	+0.7	+1.0	+0.1	+0.1	+0.1	+0.3	−2.2	−0.9	+0.5	−1.3	+1.5
,, 21	+0.2	0.0	−0.9	+0.6	−0.2	−0.3	−0.2	−0.2	+0.1	−0.1	−0.3
,, 30	0.0	+0.1	−1.0	−0.9	−0.2	−1.4	+1.8	−0.7	+0.6	−1.3	−0.3
Nov. 7	−1.4	−0.8	+0.8	−0.2	−0.7	−0.1	0.0	+0.3	+1.0	−0.1	−0.5
,, 10	+0.7	+0.2	+0.3	0.0	−1.0	+0.2	+0.5	−0.3	−0.9	+0.9	+0.3
,, 12	−1.5	−0.4	+1.2	+0.8	+0.9	−0.1	−0.3	+0.2	−0.8	+0.1	+1.0
,, 21	+0.6	+0.4	+0.6	−0.2	0.0	+0.2	+0.1	+0.9	0.0	+0.4	−1.3
Dec. 15	+0.7	−0.4	−0.7	−0.4	+0.9	+1.1	+0.4	+0.5	−0.7	+1.4	−0.1

Probable error for a

76 Dra

	1	2	3	4	5	6	7	8	9	10	11
1902											
May 20 E.	−0.1	+1.0	+0.4	−0.9	−0.5	+0.2	−0.6	−0.2	...	...	+0.1
,, 23 E.	0.0	−1.2	+2.2	+0.5	+0.2	+1.2	+0.2	−0.1	+1.2	+0.4	+0.1
,, 28 E.	−0.3	−0.7	−0.5	0.0	−1.0	−0.6	+0.4	+1.3	−0.7	−0.5	+0.2
Nov. 17 W.	+0.3	+0.7	−1.0	−0.3	+1.5	−0.8	−0.2	−0.3	0.0	+0.1	−0.8
Nov. 21 W.	−0.1	+0.3	−0.9	+0.9	0.0	+0.2	+0.2	−0.6	−0.6	0.0	+0.4

Probable error for a

In these errors there seems to me no tendency to systematic progression with the declination ; the large value found from the observations of *a Cephei* seems entirely due to two ill-judged transits as wires 23, 25 on November 7. I consider that these errors confirm the conclusion of § 3 on the standard form of equation, in which the collimation constant has always the same coefficient.

[illegible] 10′.

[illegible]	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
[illegible]	−0″·3	−0″·4	−0″·4	+0″·2	−0″·8	+1″·2	−0″·5	+0″·1	−0″·1	+1″·1	−1″·4	+2″·2	±0″·63
[illegible]	−0·8	−0·1	−0·3	−0·4	−0·4	+0·1	−0·9	−0·2	+0·2	+0·7	−1·1	+0·7	0·41
[illegible]	−0·7	+0·5	+1·4	−1·0	−1·2	−0·7	+0·9	+0·9	−0·4	−3·0	+1·3	−2·9	0·78
[illegible]	+1·4	+0·3	−0·9	+0·8	+0·3	−0·4	−0·7	−0·5	−0·3	−0·3	+1·0	−0·2	0·51
[illegible]	−0·5	+0·5	+0·4	+0·4	+1·9	−0·2	−0·3	−0·8	+0·2	+0·8	+0·8	+0·3	0·51
	+0·8	−0·7	...	−0·1	+0·1	...	+1·4	+0·3	0·0	+0·5	−0·9	−0·1	0·37

[illegible] ±0″·562.

[illegible] 1′.

	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
[illegible]	−0″·5	−1″·0	+0″·2	−0″·5	+0″·3	−1″·0	−0″·1	+0″·7	+0″·5	+0″·1	+0″·2	+0″·9	±0″·54
[illegible]	+0·5	+1·2	+0·1	−0·5	−0·2	−0·1	+0·9	+0·4	−1·1	−0·2	−0·3	−0·3	0·34
[illegible]	+0·4	−0·1	+0·3	−0·3	+0·5	−0·6	+0·3	+0·7	+0·6	+1·1	+0·3	+0·1	0·19
[illegible]	+0·2	−1·3	+0·7	+1·1	+0·8	+0·7	+0·2	+0·1	−0·1	−0·5	0·0	−0·4	0·45
[illegible]	−0·2	+0·6	−0·2	+0·7	−0·5	−0·4	−0·1	−0·5	+0·6	−0·5	+0·2	−1·0	0·36
[illegible]	−0·7	+0·7	−0·4	0·0	−0·5	+0·7	−0·7	−1·1	+0·3	−0·3	−0·8	+1·0	0·53
[illegible]	+0·1	−0·7	−0·8	−0·1	0·0	+0·4	−0·5	−0·6	−0·1	+0·7	+0·5	−0·2	0·35
[illegible]	0·0	+0·5	−0·1	−0·7	−0·3	+0·1	−0·3	0·0	−0·4	−0·5	+0·2	0·0	0·38

[illegible] ±0″·436.

[illegible] + 82° 10′.

[illegible]	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
[illegible]	−0″·6	+1″·0	+0″·5	−0″·5	+0″·2	−0″·2	+0″·9	+0″·1	+0″·2	−0″·5	−0″·6	+0″·2	±0″·36
[illegible]	−0·2	−0·6	−1·1	−0·3	−1·0	+0·8	−0·8	+0·5	−0·5	−0·6	+0·3	+0·2	0·51
[illegible]	+0·5	−0·3	0·0	+1·0	+0·5	0·0	+1·9	−0·7	+0·4	+0·3	−0·3	−0·3	0·45
[illegible]	+0·5	−0·3	+0·7	+0·1	−0·1	−0·3	−0·6	−0·3	+0·3	+1·2	+0·7	−0·3	0·45
[illegible]	−0·3	0·0	0·0	−0·1	+0·2	−0·2	−1·5	+0·5	−0·2	−0·6	...	...	0·34

[illegible] ±0″·429.

If all the observations are collected in one group—1027 in number—the probable error of a single observation emerges at ±0″·473, and the probable error of the mean of twenty-five such observations at ±0″·097. This error covers the error of the chronograph and of the inconsistencies of the observer during the transit. Errors which it does not cover are fluctuations in personality of the observer between one transit and another, fluctua-

tions if any in the clock, anomalous refraction, anomalous changes in the collimation constant. It will appear below that these errors in all amount to about four times the above amount.

I shall now give in the following table the wire intervals as derived from the different stars :—

Observed Wire Intervals from Different Stars minus Intervals adopted from Polar Stars (p. 360).

	α Coronæ W. +27° 3′.	ζ Persei E. +31° 36′.	η Aurigæ E. +41° 6′.	θ Boötis E. +52° 18′.	α Cephei W. +62° 10′.	ε Draconis W. +70° 1′.	76 Draconis. +82° 10′.
	″	″	″	″	″	″	″
1	−0·15	−2·02	−1·31	−0·05	−0·08	−0·65	−0·29
2	+0·91	−1·71	−0·61	+0·01	−0·11	−0·10	+0·11
3	+0·44	−1·89	−1·24	+0·32	+0·26	−0·17	+0·32
4	+0·94	−1·88	−1·16	−0·32	−0·19	+0·03	+0·10
5	+0·33	−1·65	−0·86	+0·33	+1·21	+0·28	+0·25
6	+0·76	−0·94	−1·13	+0·02	+0·66	−0·21	+0·04
7	+0·25	−1·44	−0·30	+0·45	+0·43	−0·06	−0·17
8	+0·47	−0·73	−0·34	−0·47	−0·12	−0·52	+0·33
9	−0·06	−0·90	−0·35	+0·04	+0·55	+0·07	+0·47
10	+0·32	+0·64	−0·06	+0·84	−0·26	+0·06	−0·16
11	+0·06	−0·11	+0·28	+0·08	+0·42	+0·24	+0·10
12	+0·41	+0·87	−0·48	−0·03	−0·10	+0·39	+0·41
13	−0·56	−0·24	−0·54	+0·02	+0·08	+0·38	−0·60
14	−0·12	+0·03	+0·08	+0·32	−0·36	−0·16	+0·54
15	−0·41	+0·72	+0·52	+0·13	+0·27	+0·14	+0·11
16	−0·57	+0·69	+0·96	+0·33	+0·43	−0·03	+0·02
17	+0·18	+0·29	+0·23	−0·52	+0·26	+0·04	−0·18
18	−0·02	+1·12	+0·60	+0·11	+0·11	+0·04	+0·19
19	−0·56	+1·47	+1·37	−0·16	−0·06	+0·31	+0·46
20	+0·24	+0·71	+0·44	−0·47	−0·31	−0·03	+0·59
21	−0·94	+1·32	+0·74	−0·23	−0·72	−0·03	−0·17
22	−0·65	+0·82	+0·18	−0·81	−0·92	−0·11	−0·81
23	−0·91	+1·12	+0·77	−0·10	−0·71	−0·19	−0·12
24	−0·48	+1·31	+1·32	+0·17	+0·10	−0·01	−1·32
25	−0·36	+2·60	+1·24	+0·74	−0·06	+0·85	−0·21

It is clear that a large part of these quantities are accidental errors, for the probable error of a single entry is from ±0″·20 to ±0″·30. But if we seek their systematic features, we must write in the notation of § 2.

$$\text{Tabulated quantity} = \Delta\zeta_r \mp \cot t_0\, \zeta_r\gamma_r'' \sin 1''$$

where the lower sign refers to a transit east, and $\Delta\zeta_r$ is a correction to the adopted wire interval after the rth wire at its middle point, and γ_r is the inclination of that wire, reckoned positive when the west end is lowest. If we add the equations for the three east stars, and those of the three west stars for each wire, and solve for $\Delta\zeta_r$, and $\zeta_r\gamma_r \sin 1''$, we get the results of the follow ing table. I have included in it the unexplained residuals of the different stars (Observed – Computed).

Inclinations of the Separate Wires deduced from Table (p. 366).

	$\Delta\zeta_r$.	$\zeta_r\gamma_r' \sin 1''$.	α Coronæ W.	ζ Pers. E.	η Aur. E.	θ Bööt. E.	α Ceph. W.	ε Drac. W.	76 Drac.
	″	″	″	″	″	″	″	″	″
1	−0·68	+0·50	−0·34	−0·69	−0·21	+0·91	+0·41	−0·10	−0·39
2	− ·24	+ ·60	+ ·11	− ·70	+ ·13	+ ·58	− ·09	− ·02	− ·35
3	− ·34	+ ·66	− ·36	− ·70	− ·35	+1·02	+ ·36	·00	− ·66
4	− ·38	+ ·82	− ·10	− ·44	− ·09	+ ·51	− ·11	+ ·20	− ·48
5	− ·02	+ ·79	−1·02	− ·61	− ·18	+ ·78	+ ·94	+ ·09	− ·27
6	− ·10	+ ·65	− ·26	·00	− ·48	+ ·48	+ ·52	− ·28	− ·14
7	·09	+ ·38	− ·32	·86	+ ·11	+ ·75	+ ·38	− ·07	+ ·08
8	− ·27	+ ·27	+ ·27	− ·11	+ ·16	− ·05	− ·05	− ·32	− ·60
9	− ·09	+ ·35	− ·58	− ·36	+ ·03	+ ·32	+ ·51	+ ·07	− ·56
10	+ ·25	− ·26	+ ·52	+ ·05	− ·53	+ ·45	− ·41	− ·12	+ ·41
11	+ ·17	+ ·09	− ·27	− ·16	+ ·19	− ·04	+ ·22	+ ·05	+ ·07
12	+ ·18	+ ·07	+ ·11	+ ·78	− ·60	− ·17	− ·31	+ ·19	− ·23
13	− ·13	+ ·13	− ·65	+ ·06	− ·30	+ ·22	+ ·16	− ·48	+ ·47
14	− ·05	− ·21	+ ·29	− ·19	− ·05	+ ·25	− ·23	− ·06	− ·59
15	+ ·21	− ·27	− ·15	+ ·16	+ ·54	− ·23	+ ·09	·00	+ ·10
16	+ ·28	− ·43	− ·11	− ·14	+ ·42	− ·19	+ ·31	− ·01	+ ·26
17	+ ·09	+ ·10	− ·08	+ ·33	+ ·22	− ·55	+ ·13	− ·24	+ ·27
18	+ ·31	− ·34	+ ·26	+ ·37	·00	− ·39	− ·07	− ·18	+ ·12
19	+ ·37	− ·59	+ ·09	+ ·34	+ ·50	− ·85	− ·21	+ ·09	− ·09
20	+ ·09	− ·16	+ ·43	+ ·41	+ ·22	− ·65	− ·34	− ·08	− ·50
21	− ·02	− ·70	+ ·29	+ ·44	+ ·17	− ·60	− ·44	+ ·17	+ ·15
22	− ·23	− ·37	+ ·22	+ ·57	+ ·10	− ·78	− ·55	− ·22	+ ·58
23	− ·04	− ·71	+ ·36	+ ·24	+ ·21	− ·45	− ·41	+ ·03	+ ·08
24	+ ·36	− ·63	+ ·25	+ ·14	+ ·43	− ·54	− ·03	− ·21	+1·68
25	+ ·79	− ·82	+ ·27	+ ·75	− ·24	− ·50	− ·55	+ ·27	+1·00

The quantities $\Delta\zeta$ indicate a slight but clear tendency to estimate the intervals less by eye and ear—from which they were

adopted—than by chronograph. Derived from the wires 1-r this tendency increases each interval on the average 0″·13 derived from 14–25 the amount is 0″·16.

The quantities $\zeta_r \gamma_r$ show that besides minor inequalities c the inclinations of the wires to one another the whole plate i slightly tilted. Deriving the amount from the first, second fourth, fifth tallies successively the inclination of the mean wir to the horizontal appears at 710″, 584″, 649″, 682″ respectively or, taking all together, 670″, the west end standing highest.

§ 7. *Collected Instrumental Constants.*

In any group of observations, before any information can b derived about the places of the stars observed, it is necessary t determine the collimation constant of the instrument, z, and th clock error. In addition to these I have determined $\Delta\phi$ th latitude correction whenever there were ten or more stars to de with, and in some cases when there were fewer. In the fin form of discussion explained above the quantity called $10z$ is

$$10z = \tfrac{1}{25}\Sigma_{25}(z_r - r_r) + (1 - \sin\bar{\delta})\sec^2\phi_0\Delta\phi$$

where z_r is the elevation of the rth wire of the observing talli above the true colatitude circle, and r_r is the refraction apparent Z.D. $90° - (\phi_0 + z_r)$, at mean state of atmosphe barometer 30·0 in., thermometer 50°·0, as adopted in the Gree wich Table. ϕ_0 is taken at 54° 46′ 6″·2, and $\bar{\delta}$ at 52° 2′. Hen the values of $10z$ are comparable from night to night, except f latitude variation ; but this is quite insignificant in comparis with other unexplained changes in $10z$.

The true latitude at date is

$$\phi_0 + \Delta\phi = 54° \; 46' \; 6''{\cdot}2 + \Delta\phi$$

The following are the results obtained since 1901 October 2 The column "mean v" must not be taken too rigorously as measure of the exactness of the observing, as it refers to differe groups of stars on different nights. Up to 1901 Nov. 15 a meth of reduction and discussion substantially the same as M Chandler's was adopted, the observations being taken of equ weight in respect to the clock correction ; but they were co bined by means of Least Squares. After that date the meth was the one explained in § 3, but curvature and refraction w first allowed for after 1901 December 7.

Latitude and Collimation.

Date. 1901.	No. of Stars Observed.	Mean z.	$\Delta\phi$.	10z.	$10\Delta z$.
Oct. 26	16	...	−0″·18	− 8″·75	...
Nov. 1	9	...	−0·60	− 10·28	...
Nov. 1	8	...	−1·78	− 11·25	...
Nov. 2	15	...	−1·08	− 10·67	...
Nov. 4	8	...	−1·64	− 9·98	...
Nov. 5	15	...	−0·71	− 12·47	..
Nov. 7	13	...	0·00	− 6·93	...
Nov 14	11	...	−0·94	− 10·96	...
Nov. 14	13	...	−0·58	− 11·77	...
Nov. 15	16	...	−0·60	− 14·44	...
Nov. 15	11	...	−0·39	− 9·52	...
Nov. 23	19	± ·060	−0·76	− 12·25	...
Nov. 27	8	± ·026	−0·32	− 9·04	...
Dec. 7	9	± ·209	+3·19	− 12·41	...
Dec. 27	13	± ·052	−0·93	− 8·49	...
Dec. 27	8	± ·028	+0·08	− 10·02	...
1902. Jan. 29	11	± ·077	−1·28	− 8·05	...
Jan. 30	16	± ·068	−1·33	− 8·22	...
Jan. 31	12	± ·038	−0·11	− 8 65	...
Feb. 17	12	± ·070	+0·07	− 12·39	...
Feb. 28	16	± ·070	+0·46	− 11·21	...
Mar. 10	16	± ·044	+0·32	+ 1·31	...
Mar. 17	12	± ·034	+0·37	+ 3·85	...
Mar. 22	9	± ·056	...	− 1·64	...
Mar. 22	5	± ·034	...	+ 1·34	...
Mar. 25	10	± ·058	−0·31	+ 2·09	...
Mar. 29	6	...	...	+ 1·27	...
Apr. 2	16	± ·044	−0·13	+ 1·23	...
Apr. 4	7	± ·049	...	+ 1·58	...
Apr. 4	6	± ·073	...	+ 0·03	...
Apr. 9	10	± ·058	+0·31	+ 0·19	...
Apr. 10	20	± ·133	+0 13	+ 5·49	...
Apr. 17	13	± ·075	+0·70	+ 4·28	...
Apr. 23	6	± ·062	...	+ 3·94	...

Date. 1902.	No. of Stars Observed.	Mean r.	$\Delta\phi$.	10s.	
Apr. 26	7	± ·043	" ...	+ 2·77	
May 1	14	± ·055	−0·05	+ 1·24	
May 2	8	± ·054	−0·49	+ 1·82	
h May 8	23	± ·076	(−0·43)	(+ 1·45)	
h May 8	12	± ·059	(−0·48)	(+ 1·06)	
h May 8	11	± ·070	(−0·03)	(+ 1·92)	
h May 8	23	± ·050	−0·46	+ 1·42	+
j May 20	10	± ·051	−0·08	+ 14·72	
May 23	16	± ·045	−0·48	+ 15·46	
May 28	15	± ·043	−0·04	+ 9·57	+
j June 26	13	± ·036	−0·06	− 21·79	
June 27	14	± ·093	+0·74	− 18·53	
June 30	19	± ·045	+0·43	− 17·11	
July 1	22	± ·037	−0·06	− 23·70	-
k Aug. 23	14	± ·058	+0·70	+ 194·35	+
Sept. 8	12	± ·054	−0·05	+ 193·33	
Sept. 16	10	± ·062	+1·76	+ 191·21	
c Sept. 18	10	± ·052	0·00	+ 3·08	
Sept. 24	24	± ·054	−0·61	+ 3·33	
Oct. 8	9	± ·067	−2·30	+ 3·24	
Oct. 11	17	± ·082	−0·10	+ 2·67	
Oct. 20	24	± ·074	−0·92	− 6·14	-
Oct. 21	12	± ·049	−0·02	− 6·47	-
Oct. 30	18	± ·058	+0·05	− 7·73	
Nov. 1	13	± ·058	−1·70	− 9·23	
Nov. 7	15	± ·080	−0·89	− 6·69	-
Nov. 10	15	± ·046	−0·63	− 8·00	-
Nov. 12	11	± ·047	+0·23	− 6·03	-
Nov. 17	21	± ·048	−0·88	− 7·62	-
Nov. 21	14	± ·060	−0·73	− 11·00	-
l Dec. 15	21	± ·110	−0·30	− 6·57	-

Notes to above Table.

* Observer, R.A.S. *a* New method of discussion first used. *b* C
and change of refraction first allowed for. *c* Collimation changed
d This group, showing sign of change in *s*, was solved in two parts.
of change in *s* being noticed among the latter observations only 1.

ught into solution and 11–16 discarded. *f* Summary discussion only, no duals adopted. *g* Four observations by R.A.S. combined with eight by .H.C. allowing for personality S − C = −0ˢ·110. *h* Signs of change in *z* g noticed this group was solved three ways: first, as usual, allowing for no ge in *z*; second, in two groups, supposing *z* constant in each; and third, in group, applying to each observation an allowance in proportion to the ge indicated by the solution in two groups. The last solution was ted. *j* Collimation constant disturbed. *k* Collimation constant disturbed emoval of dew-cap for new wind screen. *l* Observations condemned owing ratic changes in *z*.

Remarking first upon the determinations of latitude, it must remembered that the observations were in no way specially cted towards finding this quantity; on the contrary, transits small hour-angles, which are specially required, were rather ided at the present stage of the inquiry, and in consequence ifference of 1″ in $\Delta\phi$ would affect very few of the stars erved by as much as 0ˢ·1 in a transit. Remembering this, it ot surprising that, for example, on 1902 October 8 from nine s the value $\Delta\phi = -2''\cdot30$ was deduced. Besides, there seems ie tendency for the same value to reproduce itself for some e, and then to change somewhat suddenly to another. This y be due to the observations in the neighbourhood of any en date depending upon much the same group of stars, and y show that the adopted star places have not been quite urate enough to work from.

The results do not justify elaborate discussion, but grouped ether they do not seem altogether random. To unite them must take account of the weight with which each appears, l after 1901 November 23 this is very easily extracted from solution, where $10x = \Delta\phi$ is the last unknown in order, and refore the first to be evaluated in the normal equations. I it the observations of 1901 December 7 and 1902 April 10, ich the residuals indicate to be a failure from some cause I not know. Dividing the rest into convenient groups :—

Extreme Dates.	No. of Nights.	$\Delta\phi$.	Weight.
		″	
1901 Nov. 23...1902 Jan. 31	7	−0·74	15·4
1902 Feb. 17... Apr. 17	8	+0·20	25·6
May 1... July 1	10	−0·03	36·0
Aug. 23... Oct. 21	9	−0·18	34·4
Oct. 30... Dec. 15	8	−0·58	35·3
1901 Nov. 23 ...1902 Apr. 17	15	−0·15	41·0
1902 May 1... Dec. 15	27	−0·26	105·7
The whole	42	−0·23	146·7

The adopted latitude of Durham—54° 46′ 6″·2—was deter-

mined in 1843, and of course refers to the old transit circle which stands 79 feet to the north of the centre of the almucantar pier.

The cardinal question of the almucantar may be said to be the behaviour of the collimation constant z upon any one night, how much it changes systematically in the course of the night, and how much it changes erratically from star to star.

I began by assuming z to be constant, but it soon became clear that this could not be strictly maintained, from the occasions when both myself and Mr. Carpenter had observed on the same night. For instance, 1901 November 1 shows a change from $-10''\cdot28$ to $-11''\cdot25$ in $3^h\,6^m$; November 14, from $-10''\cdot96$ to $11''\cdot77$ in $3^h\,33^m$; November 15, for $-14''\cdot44$ to $-9''\cdot52$ in $3^h\,33^m$—an anomalously large change—and December 27, from $-8''\cdot49$ to $-10''\cdot02$ in $3^h\,36^m$. But we could not be sure how much of this might be a personal element. On 1902 March 22 a series of 14 stars, taken by Mr. Carpenter, showed suggestions of an erratic change in z, in the middle, and was consequently solved in two groups, the latitude correction being ignored; the first 9 stars gave $10z = -1''\cdot64$, the last 5, $10z = +1''\cdot34$. On April 4 a similar phenomenon was noticed.

Then, for a number of nights, I took out the individual z as indicated by each observation, and the same as it would have been shown if I had allowed for the residual of that individual star as determined from previous transits. The results showed in a marked way the improvement of the values of individual z's in point of consistency, and at the same time the consistency of its residuals; they also show that, though in some cases there may be erratic changes in z, there may also be a well-marked gradual change that could and should be allowed for. A series of 23 stars on May 8 gave good material for further examination of this point, especially on the effect of alternative methods of solution upon the residuals determined for particular stars. They were first solved in a single group, assuming z to be constant. The resulting instrumental corrections were $10z = +1''\cdot45$, $\Delta\varphi = -0''\cdot43$; clock correction at 0^h S.T. $= +26^s\cdot189$. The individual values of $10z$ were found, and were marked on a chart, the values of $10z$ being relieved of the residuals belonging to each particular star as determined by previous transits, and they indicated clearly enough that $10z$ increased at a uniform rate of about $+0''\cdot50$ per hour; and that the value of $10z$ given by the solution corresponds closely with that belonging to the middle of the observations. The first 12 stars and the next 11 were solved in the same way, assuming z constant in each. The results were respectively—first 12: clock correction, $+26^s\cdot188$, $10z = +1''\cdot06$, $\Delta\phi = -0''\cdot48$; second 11: clock correction $+26^s\cdot214$, $10z = +1''\cdot92$, $\Delta\phi = -0''\cdot03$—showing that $10z$ increased $+0''\cdot86$ in $1^h\,40^m$, if we take the two values to belong to the middle times of the two groups. Lastly, the 23 were solved in one group, after correcting n for each star for the

change in $1oz$ at the rate of $+0''{\cdot}50$ per hour. The results were: clock correction $+26^s{\cdot}198$, $1oz = +1''{\cdot}42$, $\Delta\phi = -0''{\cdot}46$. The last method was laborious, since it involved two solutions of the same equations—the first to find the change in $1oz$, and the second after this change had been removed from the values of n employed. It was undertaken in order to see what effect it had upon the residuals, and the conclusion was that exactly the same residuals were shown by applying directly to the residuals that emerged, on the supposition that $1oz$ was constant, the corrections that belonged to the estimated change in $1oz$. The average difference was $\pm{\cdot}003$, and nowhere did it exceed $\cdot007$. Hence it is clear that where a change in $1oz$ is perceived after solution it is perfectly safe to clear its effect from v by the method of § 3.

It is clear, at the same time, that the clock correction and the latitude correction are not sensibly modified by this procedure.

As these changes in z are of the utmost importance in the theory of the instrument—first in order to estimate reliably their amount and to allow for it, and then, if possible, to trace their cause and remove them—I have added below full detail with regard to the unexplained or accidental portion of $1oz$ as it appears in the individual transits from 1901 December 27 to 1902 December 15.

Consider the equations

$$\mp z_i + ay \mp bx + n = 0$$
$$\mp z_a + ay \mp bx + n = v$$

then z_i is the indicated value of z from an individual observation, y, x being supposed known and n given; and z_a is the adopted value of z for that observation arising from the mean value given by solution, and the estimated hourly change in z. Let v_0 be the true value which v should have, that is, the value which would give the true (unknown) coordinates of the star; then if we put

$$\mp z_b + ay \mp bx + n = v_0$$

the quantity z_b would give the true collimation of the instrument at the true time of observation, and may be conveniently examined by means of

$$z_b - z_a = \pm(v - v_0)$$

where the upper sign refers to a transit east. This quantity may be considered as a sum of the faults of the instrument, the observer, and the method of discussion; if it shows a systematic element, the method of discussion is in fault, as, for example, a uniform rate of increase or decrease could be removed by adopting differently Δz.

Of unsystematic elements, if c'' measures what is erratic instrumentally, whether due to anomalous refraction, if any, or

to failure of the instrument to regain its former Z.D. afte
turbance by motion in azimuth for setting, and if e^s de
what is erratic in the observer's record, we may take

$$z_b - z_o = \tfrac{1}{10}c'' + a \times e^s$$

where a is the same coefficient as is used above.

In making out the following table v_o has been taken
the mean of the observations of that star in all cases where
were as many as three observations ; when there were onl
or two it has been taken at zero. The latter cases are m
by an asterisk. The stars are indicated by the reference nu
attached to them in the list of collected residuals for indiv
stars, § 8 ; thus the first star, 24 E., denotes a transit east of a F
In the earlier observations several stars were observed only
and were not included when the list was made up. These
no reference number attached to them, but merely the
E. or W.

Unexplained Residuals ($z_b - z_o$) in Individual Observations from 19
December 27 *to* 1902 *December* 15.

1901 Dec. 27.	Dec. 27—*cont.*	Jan. 30—*cont.*	Jan. 31—c
24 E. − ·06*	15 W. + ·04*	E. − ·04*	21 W. − ·
128 W. ·00*	p.e. ± ·020	54 E. − ·08*	W. − ·
140 W. − ·01*		E. + ·10*	70 E. − ·
E. + ·04*	1902 Jan. 29.	12 W. + ·01*	73 E. ·
119 W. + ·01	W. ·00*	53 E. + ·07*	W. + ·
130 W. − ·04*	E. − ·10*	49 E. + ·05*	76 E. − ·
146 W. + ·13*	150 W. − ·11*	22 W. + ·05*	p.e. ± ·03
144 W. − ·08	W. − ·13*	63 E. − ·08*	
148 W. + ·02	E. + ·03*	21 W. − 04	Feb. 17.
27 E. + ·02	E. + ·02*	18 W. − ·07*	21 W. + ·
35 E. + ·04	E. + ·12*	W. − ·03*	18 W. + ·
38 E. − ·02	7 W. + ·08*	24 W. ·00*	W. + ·
33 E. − ·05	W. + ·13*	E. − ·08*	E. + ·
p e. ± ·034	E. + ·05*	p.e. ± ·05 ;	E. + ·
	51 E. − ·08*		39 W. + ·
55 E. − ·02*	p e. ± ·060	Jan. 31.	73 E. − ·
155 W. − ·04*		49 E. − ·07*	74 E. − ·
2 W. − ·01*	Jan. 30.	22 W. ·00*	76 E. − ·
17 W. − ·01*	E. + ·13*	27 W. ·00*	67 E. ·
48 E. + ·04*	2 W. + ·13*	58 E. + ·08*	36 W. − ·
153 W. + ·03*	W. − ·12*	68 E. + ·03*	35 W. − ·
56 E. − ·03*		63 E. + ·05*	p.e. ± ·04

Feb. 28.

79 E. − ·15*
67 E. + ·08*
36 W. + ·04
35 W. − ·01
E. − ·15*
84 E. + ·07*
38 W. + ·02
42 W. − ·03
31 W. + ·01
75 E. + ·05
83 E. + ·03
46 W. + ·03
89 E. + ·04
80 E. + ·02
50 W. + ·02
W. − ·05*
p.e. ± ·045

Mar. 10.

35 W. + ·10
84 E. + ·13*
38 W. − ·04
42 W. − ·02
31 W. − ·01
75 E. − ·01
83 E. − ·03
W. ·00*
46 W. + ·02
89 E. − ·02
80 E. − ·01
50 W. − ·02
W. − ·07*
94 E. − ·02
86 E. ·00
51 W. − ·03
p.e. ± ·032

Mar. 17.

75 E. ·00
83 E. + ·05
W. ·00*
46 W. − ·02
80 E. − ·10
50 W. + ·02
30 W. + ·02
53 W. − ·05*
94 E. − ·02
86 E. + ·01
51 W. − ·01
85 E. + ·06
p.e. ± ·028

Mar. 22

83 E. ·00
41 W. + ·10*
40 W. − ·01*
80 E. + ·05
50 W. + ·01
30 W. − ·03
86 E. − ·03
99 E. − ·02
85 E. + ·02
p.e. ± ·028

77 E. − ·05
101 E. + ·06
44 W. + ·02
60 W. + ·02
E. ·00*
p.e. ± ·025

Apr. 2.

30 W. + ·03
53 W. − ·01*
94 E. − ·01
86 E. ·00

Apr. 2—*cont.*

99 E. + ·10
77 E. + ·06
101 E. − ·01
44 W. + ·03
60 W. − ·01
104 E. − ·03
100 E. − ·03
61 W. + ·02
54 W. − ·01
82 E. − ·06
93 E. + ·02
92 E. + ·01
p.e. ± ·025

Apr. 4.

94 E. + ·04
86 E. + ·03
51 W. + ·03
85 E. + ·01
77 E. + ·01
101 E. − ·08
44 W. − ·06
p.e. ± ·030

60 W. − ·02
104 E. − ·01
100 E. ·00
61 W. ·00
54 W. + ·01
82 E. + ·06
p.e. ± ·018

Apr. 9.

24 W. + ·06*
43 W. + ·03*
36 W. − ·05
75 E. − ·03
83 E. − ·07

Apr. 9—*cont.*

34 W. + ·09*
46 W. − ·05
89 E. − ·02
80 E. + ·06
50 W − ·03
p.e. ± ·036

Apr. 17.

36 W. + ·06
35 W. ·00
78 E. + ·19*
64 E. − ·04*
38 W. + ·02
42 W. + ·05
31 W. + ·01
81 E. − ·08*
30 W. − ·01
48 [illegible] − ·06*
99 [illegible] − ·07
85 E. − ·03
101 E. + ·04
p.e. ± ·047

Apr. 23.

104 E. + ·04
100 E. + ·05
61 W. + ·02
54 W. ·00
82 E. − ·04
58 W. − ·05
p.e. ± ·026

Apr. 26.

85 E. − ·04
77 E. − ·03
101 E. ·00
44 W. + ·01

Apr. 26—*cont.*

106 E. + ·03*
104 E. + ·01
100 E. + ·05
p.e. ± ·020

May 1.

100 E. − ·07
61 W. + ·01
54 W. ·00
82 E. + ·02
58 W. − ·04
93 E. − ·01
92 E. + ·02
102 E. + ·06
88 E. + ·02
56 W. + ·02
96 E. − ·08*
115 E. − ·01*
111 E. + ·02*
59 W. + ·01
p.e. ± ·026

May 2.

58 W. + ·08
97 E. + ·02*
93 E. − ·01
92 E. − ·08
102 E. − ·06
88 E. ·00
56 W. − ·02
55 W. − ·03*
p.e. ± ·032

May 8.

44 W. + ·02
106 E. − ·01*
104 E. − ·01

May 8—*cont.*

100 E. + ·02
61 W. − ·03
54 W. − ·01
82 E. + ·01
92 E. + ·04
102 E. − ·01
88 E. − ·01
56 W. ·00
55 W. + ·03*
52 W. − ·17*
96 E. − ·09*
115 E. − ·04*
111 E. − ·02*
59 W. + ·01
65 W. + ·03*
113 E − ·01*
57 W. + ·06
105 E. + ·05*
110 E. + ·04
119 E. + ·04
p.e. ± ·033

May 20.

57 W. − ·05
110 E. − ·02
107 E. + ·02
70 W. + ·02
125 E. ·00
77 W. − ·10*
62 W. ·00
120 E. − ·05
132 E. − ·02
68 W. + ·08
p.e. ± ·032

May 23.

59 W. − ·02
65 W + ·14*

May 23—*cont.*

113 E. − ·01*
57 W. − ·01
110 E. − ·07
119 E. − ·04
107 E. + ·01
70 W. + ·01
125 E. + ·05
62 W. + ·01
120 E. + ·03
132 E. − ·01
68 W. − ·02
116 E. + ·04*
72 W. − ·03*
69 W. + ·06*
p.e. ± ·032

May 28.

57 W. − ·01
105 E. + ·13*
110 E. + ·06
119 E. + ·01
107 E. − ·03
70 W. − ·03
125 E. − ·05
77 W. − ·11*
62 W. − ·01
120 E. + ·01
132 E. + ·03
68 W. − ·05
116 E. − ·01*
72 W. − ·01*
69 W. + ·01*
p.e. ± ·035

June 26.

117 E. − ·01
118 E. + ·03
137 E. + ·03

June 26—*cont.*

74 W. + ·02
88 W. − ·01*
87 W. − ·04
130 E. − ·01
78 W. + ·03
76 W. − ·03
139 E. − ·06
98 W. − ·08
134 E. − ·05
81 W. − ·06
p.e. ± ·028

June 27.

66 W. − ·22*
117 E. + ·03
118 E. + ·03
137 E. − ·08
74 W. − ·04
136 E. + ·01
87 W. + ·02
130 E. − ·01
78 W. + ·02
76 W. − ·01
139 E. + ·11
98 W. + ·[illegible]
134 E. + ·[illegible]
35 W. + ·[illegible]
p.e. ± ·06

June 30.

118 E. − ·02
137 E. + ·07
74 W. + ·0[illegible]
136 E. − ·0[illegible]
87 W. ·0[illegible]
130 E. − ·1
78 W. − ·0

30—*cont.*
W. + ·04
E. − ·02
W. − ·07
E. + ·02
W. + ·01
E. − ·01
W. − ·05
E. − ·02
E. − ·03
W. − ·01
W. − ·04*
E. + ·07
± ·034

July 1.
W. − ·07*
E. − ·03
E. − ·03
E. − ·01
W. ·00
E. + ·01
W. − ·03*
W. ·00
E. + ·01
W. + ·05
W. + ·02
E. − ·03
W. − ·05
E. − ·03
W. + ·02
E. + ·03
W. + ·03
E. ·00
E. + ·01
W. ·00
W. − ·06*
E. − ·01
± ·021

Aug. 23.
130 E. + ·13
78 W. − ·10
98 W. − ·03
134 E. − ·08
81 W. + ·04
149 E. − ·01
85 W. − ·03
131 E. + 03
153 E. + ·03
90 W. + ·01
86 W. − ·05
143 E. − ·01
127 E. − ·19*
109 W. + ·04*
p.e. ± ·051

Sept. 8.
11 E. + ·01
14 E. + ·04
7 E. − ·09
148 E. − ·06*
13 E. ·00
117 W. − ·06
118 W. − ·06
116 W. + ·02
155 E. + ·09
113 W ·00*
4 E. − ·05
3 E. + ·05
p e. ± ·036

Sept. 16.
105 W. + ·01*
107 W. + ·10*
4 E. − ·06
3 E. − ·01
106 W. − ·06*

Sept. 16—*cont.*
21 E. + ·19*
133 W. − ·02*
17 E. − ·18
120 W. − ·03
124 W. + ·01
p.e. ± ·060

Sept. 18.
13 E. − ·02
99 W. + ·06*
117 W. − ·07
118 W. − ·01
116 W. − ·03
155 E. + ·06
1 E. + ·05
108 W. − ·01*
4 E. + ·14
3 E. − ·05
p.e. ± ·042

Sept. 24.
86 W. + ·07*
143 E. − ·04
127 E. − ·03*
83 W. − ·02*
109 W. − ·02*
105 W. − ·05*
6 E. + ·02*
84 W. − ·08*
112 W. + ·08*
102 W. + ·02
89 W. + ·03*
110 W. + ·01
5 E. − ·04
11 E. + ·04
14 E. + ·03
7 E. + ·07

Sept. 24—*cont.*
148 E. − ·05*
123 W. + ·06*
18 E. + ·06*
104 W. − ·07*
118 W. + ·08
116 W. ·00
155 E. − ·11
p.e. ± ·036

Oct. 8.
95 W. + ·05*
102 W. ·00
152 E. + ·02*
110 W. + ·07
5 E. + ·02
100 W. + ·02*
11 E. − ·09
14 E. − ·07
99 W. − ·10*
p.e. ± ·040

Oct. 11.
84 W. − ·18*
112 W. − ·09*
95 W. − ·01*
102 W. + ·01
110 W − ·09
5 E. + ·02
(100 W. + ·29*)
11 E. + ·02
14 E. ·00
7 E. + ·03
13 E. + ·03
18 E. − ·01*
117 W. + ·12
118 W. + ·07
116 W. − ·07

Oct. 11—*cont.*

155 E. + ·03
1 E. − ·02
p.e. ± ·047
(p.e. ± ·065)

Oct. 20.

8 E. + ·12*
17 E. + ·14
120 W. ·00
124 W. − ·02
138 W. + ·07*
23 E. − ·06*
22 E. − ·01
119 W. − ·03
134 W. + ·11
34 E. − ·02
121 W. − ·02
28 E. − ·08
125 W. − ·10
144 W. + ·11
29 E. + ·07
44 E. − ·01
27 E. + ·06
35 E. − ·08
38 E. − ·02
126 W. − ·04
36 E. − ·08
129 W. − ·05
136 W. − ·03
p.e. ± ·047

Oct. 21.

120 W. + ·01
124 W. + ·02
138 W. + ·04*
23 E. − ·01*
22 E + ·06

Oct. 21—*cont.*

119 W. − ·03
134 W. − ·05
34 E. − ·02
121 W. + ·04
28 E. + ·01
141 W. − ·02
125 W. + ·01
p.e. ± ·021

Oct. 30.

22 E. − ·04
119 W. + ·04
134 W. − ·06
34 E. − ·05
121 W. − ·02
141 W. + ·03
125 W. + ·08
144 W. − ·06
148 W. − ·04
44 E. + ·06
27 E. − ·01
35 E. + ·03
38 E. + ·02
126 W. + ·01
36 E. ·00
129 W. − ·02
136 W. + ·01
37 E. + ·04*
p.e. ± ·027

Nov. 1.

118 W. − ·10
116 W. + ·06
155 E. − ·09
1 E. − ·02
108 W. + ·01*
4 E. − ·04

Nov. 1—*cont.*

9 E. − ·02*
3 E. ·00
106 W. − ·09*
21 E. + ·11*
19 E. − ·02*
17 E. + ·05
120 W. + ·01
p.e. ± ·040

Nov. 7.

34 E. + ·11
121 W. + ·04
141 W. + ·10
125 W. − ·06
144 W. − ·01
29 E. − ·12
148 W. − ·09
44 E. − ·03
27 E. + ·01
35 E. + ·05
38 E. ·00
126 W. − ·05
36 E. + ·04
129 W. + ·07
136 W. + ·01
p.e. ± ·044

Nov. 10.

121 W. − ·02
28 E. + ·03
141 W. − ·10
125 W. + ·01
144 W. + ·03
29 E. − ·04
148 W. + ·06
44 E. − ·01
27 E. + ·02 *

Nov. 10—*cont.*

35 E. + ·02
38 E. + ·04
126 W. + ·01
36 E. ·00
129 W. + ·02
136 W. + ·03
p.e. ± ·026

Nov. 12

121 W. + ·02
28 E. ·00
141 W. ·00
125 W. + ·07
144 W. − ·01
29 E. + ·05
148 W. ·00
44 E. + ·06
27 E. − ·04
35 E. − ·04
38 E. − ·06
p.e ± ·028

Nov. 17.

144 W. − ·07
29 E. + ·03
148 W + ·03
44 E. − ·07
27 E. − ·03
35 E. − ·02
38 E. + ·03
126 W. + ·06
36 E. + ·07
129 W. − ·01
136 W. + ·04
33 E. + ·07
41 E. + ·02
143 W ·00*

v. 17—*cont.*	Nov. 21—*cont.*	Dec. 15.	Dec. 15—*cont.*
32 W. − ·05*	141 W. − ·02	23 E. + ·18	35 E. + ·04
52 E. + ·10*	125 W. + ·02	119 W + ·06	38 E. + ·07
39 W. − ·09*	144 W. + ·10	134 W. + ·19	36 E. − ·04
3 W. + ·05*	36 E. − ·03	34 E. − ·03	129 W. + ·09
12 E. − ·01*	129 W. − ·01	121 W. − ·01	136 W. − ·01
4 W. + ·03*	136 W. − ·04	28 E. − ·14	37 E. + ·05
39 E. − ·09*	37 E. + ·09*	141 W. − ·19	26 E. − ·18*
p.e. ± ·037	33 E. − ·02	125 W. − ·12	41 E. − ·05
	41 E. − ·04*	144 W. − ·10	143 W. − ·07
	143 W. − ·04*	29 E. − ·01	p.e. ± ·072
Nov. 21.	132 W. − ·05*	148 W. + ·10	
21 W. − ·05	52 E. + ·07*	27 E. + ·13	
28 E. + ·03	p.e. ± ·034		

Note.—*p.e.* denotes the probable error of a single observation, and is equal ·6745 × the square root of the mean of the squares of the residuals ve it.

On 1902 October 11 the star 100 W. which was observed on only one r occasion gave an anomalous residual; the p.e. is shown excluding this dual, and also (in brackets) including it.

Besides the observations recorded above, a number of sets re discarded in the earlier part of the year. This was because y showed clearly that a single value of z would not accord h them all, and I had not then adopted any method I con-ered satisfactory for allowing for a change in z. Some sets) were rejected because they were too short to be worth ucing. Under these heads were rejected—on January 18, stars; on January 31, 7 stars; on March 22, 3 stars; on rch 25, 19 stars; on March 29, 15 stars; and on April 10, stars, being in each case the whole set observed by one or er observer. In some of these cases all that was wanted was allowance for a uniform change in z. On the same plan, the ervations of June 27, included above, should have either been carded or else treated for the change in z which they exhibit.

The whole of the above list includes 608 residuals; omitting ne, the probable error of a single observation is ±·0402, or in D. ±0″·402; omitting the complete sets of June 27 and cember 15, there are 573 stars with a probable error of 0″·375.

It is clear that this discordance would be materially reduced d the number of stars with one or two observations only ayed a smaller part. For example, on May 8 the average dis rdance for stars observed three times and more is ±·022; for e others, ±·050; or, again, compare the sets of January 29, 30 th that of April 2; or, again, note that on July 1 of 22 stars,

the only residuals which exceed 0·05 are those of stars not observed three times.

It is also clear that some of the earlier sets which were not examined for a change in z would be greatly improved had such a change been allowed for. The sets of April 23, April 26, May 2, would be almost reduced to zero by such an allowance; June 27 requires the allowance also; the two sets of April 4 show such a change, but, curiously, in opposite directions; and there are other cases only a little less clearly marked.

If z always changed uniformly with the time, the amount of this change would matter little. For instance, October 21, on which the change in $10z$ was estimated at $2''{\cdot}07$ per hour, gives rather smaller residuals than October 30, when it was estimated at zero. By the method of discussion employed above one state is as safely dealt with as the other. But it is clear from the considerable oscillations in the probable errors of the above sets that there is also an erratic element, and that this erratic element is of very considerable amount, and is sometimes sensibly absent for long periods together. How far this element is observational, or instrumental, or atmospheric, I am not prepared at once to say. In the later months, when the probable error was somewhat greater than in the earlier months, the clock was not going so well, and this may have had some small effect, but would certainly not account for all. A full understanding of this matter is the key to the use of the almucantar; and if it is at present somewhat obscure, it illustrates the essential simplicity of the instrument that we can so soon and so certainly fix attention upon a single requisite.

The average of the first three residuals of each night exceeds that of the last three; they are respectively ·050 and ·041. This can only be due to some observational fault in the way work is begun each night, and ought to disappear in future series.

§ 8. *Observed Residuals, Correcting Star Places.*

The following is a list of the stars observed from 1901 December 27 to 1902 December 15. The places to which these observed residuals are corrections are the places of the *Nautical Almanac* or of the Berlin *Astronomisches Jahrbuch* of 1902, the latter indicated by the letters B.J. The quantities required for deducing the corrections to R.A. and Decl., being the coefficients $1{\cdot}5 \sin t_0 \cos \delta_0$, $\pm \cos t_0$, are given with each star; thus, for example, we have from α *Cephei*, No. 136, taking the means of the recorded quantities

$$\cdot 656\ \Delta\alpha^s - 0{\cdot}351\ \frac{\Delta\delta''}{10} = -0{\cdot}05$$

$$\cdot 656\ \Delta\alpha^s + 0{\cdot}351\ \frac{\Delta\delta''}{10} = -0{\cdot}11$$

or

$$\Delta\alpha = -0^s{\cdot}12,\quad \Delta\delta = -0''{\cdot}86$$

ıe noticed that in most of the following cases I have ıervations both east and west: this arose from the ıs in the observing which must always beset the first ; of a new instrument. It is not at present my ıffer a schedule of corrections to the two catalogues The following list is rather put forward to show how rent observations of the same star agree with one he present stage.

bserved Residuals, 1901 *December* 27 *to* 1902 *November* 21.

	4.	7.	12.
	8 Androm. B.J.	o Cassiop. B.J.	φ Persei, B.J.
	·750 ± ·812.	·845 ± ·547.	·825 ± ·513.
	E.	E.	W.
	1902.	1902.	1902.
02	Sept. 8 ·00	Sept. 8 −·11	Jan. 30 −·01
05	16 −·01	24 +·05	
05	18 +·19	Oct. 11 +·01	13.
	Nov. 1 +·01	W.	e Cassiop.
	W.	1902.	·637 ± ·338.
	1902.	Jan. 29 −·08	E.
	Nov. 17 −·05	8.	1902.
		ζ Androm. B.J.	Sept. 8 −·06
		·525 ± ·924.	18 −·08
		E.	Oct. 11 −·03
01	5.	1902.	
	a Cassiop.	Oct. 20 +·12	14.
13	·756 ± ·433.	9.	50 Cassiop. B.J.
	E.	β Androm.	·453 ± ·225
	1902.	·832 ± ·736.	E.
	Sept. 24 −·02	E.	1902
	Oct. 8 −·04	1902.	Sept. 8 ·00
	11 +·04	Nov. 1 −·02	24 −·01
		11.	Oct. 8 −·11
		43 Cassiop. B.J.	11 −·04
08		·550 ± ·281.	
02	6.	E.	15.
02	21 Cassiop. B.J.	1902.	γ Androm.
03	·394 ± ·194.	Sept. 8 +·08	·865 ± ·633.
	E.	24 +·11	W.
	1902.	Oct. 8 −·02	1901.
05	Sept. 24 +·02	11 +·09	Dec. 27 −·04

17.
β Trianguli.
·825 ± ·745.

E.		
1902		
Sept.	16	−·16
Oct.	20	+·16
Nov.	1	+·07
W.		
1901.		
Dec.	27	+·01

18.
55 Cassiop. B.J.
·581 ± ·300.

E.		
1902.		
Sept.	24	+·06
Oct.	11	−·01
W.		
1902.		
Jan.	30	+·07
Feb.	17	−·07

19.
θ Persei, B.J.
·836 ± 532.

1902.		
Nov.	1	−·02

21.
τ Persei, B.J.
·803 ± ·483.

E.		
1902.		
Sept.	16	+·19
Nov.	1	+·11

W.

1902.		
Jan.	30	+·05
	31	+·04
Feb.	17	−·06

22.
ρ Persei, B J.
·858 ± ·684.

1902.		
Oct.	20	+·02
	21	+·09
	30	−·01
W.		
1902.		
Jan.	30	−·05
	31	·00

23.
β Persei.
·864 ± ·652.

E.		
1902.		
Oct.	20	−·06
	21	·01
(Dec.	15	+·14)

24.
α Persei.
·831 ± ·522.

E.		
1901.		
Dec.	27	−·06
W.		
1902.		
Jan.	30	·00
Apr.	9	−·06

27.
ζ Persei.
·781 ± ·791.

E.		
1901.		
Dec.	27	+·02
1902.		
Oct.	20	+·06
	30	−·01
Nov.	7	+·01
	10	+·02
	12	−·04
	17	−·03
(Dec.	15	+·13)
W.		
1902.		
Jan.	31	·00

28.
ε Persei.
·862 ± ·664.

E.		
1902.		
Oct.	20	−·15
	21	−·06
Nov.	10	−·04
	12	−·07
	17	−·04
(Dec.	15	−·21)

29.
ξ Persei, B.J.
·836 ± ·729.

E.		
1902.		
Oct.	20	+·05
Nov.	7	−·14
	10	−·06
	12	+·03
	17	+·01
(Dec.	15	−·03)

30.
Groomb. 848
·363 ± ·17

W.		
1902.		
Mar.	17	−
	22	+
Apr.	2	−
	17	+

31.
4 Camel. B
·748 ± ·42

W.		
1902.		
Feb.	28	+
Mar.	10	+
Apr.	17	+

33.
ι Auriga
·804 ± ·7

E.		
1901.		
Dec.	27	
1902.		
Nov.	17	
	21	

34.
10 Camel.
·689 ± ·3

E.		
1902.		
Oct.	20	
	21	
	30	
Nov.	7	
(Dec.	15	
W.		
1902.		
Apr.	9	·

35.
ε Aurigæ, B.J.

·863 ± ·606.

1901.	
)ec. 27	+ ·10
1902.	
ct. 20	− ·02
30	+ ·09
lov. 7	+ ·11
10	+ ·08
12	+ ·02
17	+ ·04
)ec. 15	+ ·10)

W.

1902.	
eb. 17	+ ·16
28	+ ·10
lar. 10	− ·01
pr. 17	+ ·09

36.
η Aurigæ.

·865 ± ·644.

E.

902.	
20	− ·12
30	− ·04
v. 7	·00
10	− ·04
17	+ ·03
21	− ·07
ec. 15	− ·08)

W.

1902	
b. 17	+ ·05
28	− ·03
r. 9	+ ·06
17	− ·05

37.
μ Aurigæ, B.J.

·857 ± ·685

E.

1902.	
Oct. 30	+ ·04
Nov. 21	+ ·09
(Dec. 15	+ ·12)

38.
α Aurigæ.

·855 ± ·574

E.

1901.	
Dec. 27	− ·04
1902.	
Oct. 20	− ·04
30	·00
Nov. 7	− ·02
10	+ ·02
12	− ·08
17	+ ·01
(Dec. 15	+ ·05)

W.

1902.	
Feb. 28	− ·11
Mar. 10	− ·05
Apr. 17	− ·11

39.
β Tauri.

·711 ± ·842

E.

1902.	
Nov. 17	− ·09

W.

1902.	
Feb. 17	− ·03

40.
ο Aurigæ, B.J.

·828 ± ·519

W.

1902.	
Mar. 22	+ ·01

41.
β Aurigæ.

·850 ± ·587

E.

1902.	
Nov. 17	·00
21	− ·04
(Dec. 15	− ·07)

W.

1902.	
Mar. 22	− ·10

42.
θ Aurigæ.

·850 ± ·703

E.

1902.	
Nov. 17	− ·01

W.

1902.	
Feb. 28	·00
Mar. 10	− ·01
Apr. 17	− ·08

43.
1 Gem

·498 ± ·933

W.

1902.	
Apr. 9	− ·03

44.
22 H. Camel. B.J.

·511 ± ·258

E.

1902.	
Oct. 20	·00
30	+ ·07
Nov. 7	− ·02
10	·00
12	+ ·07
17	− ·06

W.

1902.	
Mar. 22	+ ·02
Apr. 2	+ ·01
4	+ ·10
26	+ ·03
May 8	+ ·02

46.
θ Gem. B.J.

·819 ± ·732

E.

1902.	
Feb. 28	− ·07
Mar. 10	− ·06
17	− ·02
Apr. 9	+ ·01

48.
α_2 Gem.

·790 ± ·783

E.

1901.	
Dec. 27	+ ·04

W.

1902.	
Apr. 17	+ ·06

49.
κ Gem. B.J.

·570 ± ·909

E.

1902.		
Jan.	30	+ ·05
	31	− ·07

50.
β Gem.

·705 ± ·846

W.

1902.		
Feb.	28	+ ·03
Mar.	10	+ ·07
	17	+ ·03
	22	+ ·04
Apr.	9	+ ·08

51.
π Gem. B.J.

·814 ± ·758

E.

1902.		
Jan.	29	− ·08

W.

1902.		
Mar.	10	− ·04
	17	− ·06
Apr.	4	− ·10

52.
Groomb. 1374 B.J.

·401 ± ·197

E.

1902.		
Nov.	17	+ ·10
	21	+ ·07

W.

1902.		
May	8	+ ·17

53.
6 Caneri.

·698 ± ·850

E.

1902.		
Jan.	30	+ ·07

W.

1902.		
Mar.	17	+ ·05
Apr.	2	+ ·01

54.
31 Lyncis, B.J.

·863 ± ·608

E.

1902.		
Jan.	30	− ·04

W.

1902.		
Apr.	2	− ·05
	4	− ·07
	23	− ·06
May	1	− ·06
	8	− ·05

55.
o Urs. Maj.

·676 ± ·366

E.

1901.		
Dec.	27	− ·02

W.

1902.		
May	2	+ ·03
	8	− ·03

56.
ι Urs. Maj.

·840 ± ·538

E.

1901.		
Dec.	27	− ·03

W.

1902.		
May	1	·00
	2	+ ·04
	8	+ ·02

57.
σ_2 Urs. Maj. B.J.

·551 ± ·282

W.

1902.		
May	8	− ·14
	20	− ·03
	23	− ·07
	28	− ·07

58.
α Lyncis.

·829 ± ·740

E

1902.		
Jan.	31	+ ·08

W.

1902.		
Apr.	23	+ ·05
May	1	+ ·04
	2	− ·08

59.
θ Urs. Maj.

·805 ± ·486

W.

1902.		
May	1	− ·04
	8	− ·04
	23	− ·01

60.
ε Leonis.

·550 ± ·916

W.

1902.		
Mar.	22	+ ·01
Apr.	2	+ ·04
	4	+ ·05

61.
μ Leonis.

·646 ± ·877

W.

1902.		
Apr.	2	+ ·03
	4	+ ·05
	23	+ ·03
May	1	+ ·04
	8	+ ·08

62.
Groomb. 1586 B.J.

·421 ± ·207

W.

1902.		
May	20	+ ·09
	23	+ ·08
	28	+ ·10

63.
λ Urs. Maj. B.J.
·864 ± ·609
E.
1902.
Jan. 30 −·08
31 +·05

64.
ζ Leonis.
·534 ± ·921
E.
1902.
Apr. 17 −·04

65.
μ Urs. Maj.
·865 ± ·631
W.
1902.
May 8 −·03
23 −·14

66.
9 H. Drac. B.J.
·352 ± ·171
W.
1902.
June 27 +·22

67.
42 Leo Min. B.J.
·773 ± ·798
E.
1902.
Feb. 17 ·00
28 +·08

68.
β Urs. Maj.
·744 ± ·421
E.
1902.
Jan. 31 +·03
W.
1902.
May 20 −·11
23 −·01
28 +·02

69.
α Urs. Maj.
·655 ± ·350
W.
1902.
May 23 −·06
28 −·01

70.
ψ Urs. Maj.
·859 ± ·586
E.
1902.
Jan. 31 −·05
W.
1902.
May 20 −·03
23 −·02
28 +·02

72.
χ Urs. Maj. B.J.
·840 ± ·539
W.
1902.
May 23 +·03
28 +·01

73.
γ Urs. Maj.
·780 ± ·457
E.
1902
Jan. 31 ·00
Feb. 17 −·09

74.
δ Urs. Maj. B.J.
·733 ± ·412
E.
1902.
Feb. 17 −·09
W.
1902.
June 26 −·04
27 +·02
30 −·04
July 1 −·02

75.
δ Can. Ven. B.J.
·865 ± ·632
E.
1902.
Feb. 28 +·06
Mar. 10 ·00
17 +·01
Apr. 9 −·02

76.
76 Urs. Maj. B.J.
·635 ± ·337
E.
1902
Jan. 31 −·05
Feb. 17 −·03
W.
1902.
June 26 +·08
27 +·06
30 +·01
July 1 +·03

77.
31 Comæ.
·698 ± ·850
E.
1902.
Mar. 22 −·06
Apr. 2 +·05
4 ·00
26 −·04
W.
1902.
May 20 +·10
28 +·11

78.
ε Urs. Maj.
·749 ± ·426
E.
1902.
Apr. 17 +·19
W.
1902.
June 26 −·12
27 −·11
30 −·08
July 1 −·14
Aug. 23 +·01

79.
8 Drac. B.J.
·584 ± ·301
E.
1902.
Feb. 28 −·15

80.
α Can. Ven.

·859 ± ·678

E.

1902.		
Feb.	28	+ ·07
Mar.	10	+ ·04
	17	− ·05
	22	+ ·10
Apr.	9	+ ·11

W.

1902.		
July	1	+ ·07

81.
η Urs. Maj.

·828 ± ·518

E.

1902.		
Apr.	17	− ·08

W.

1902.		
June	26	+ ·03
	30	− ·04
July	1	− ·05
Aug.	23	− ·07

82.
11 Boötis, B.J.

·691 ± ·854

E.

1902.		
Apr.	2	− ·05
	4	+ ·07
	23	− ·03
May	1	+ ·03
	8	+ ·02

83.
α Drac.

·605 ± ·316

E.

1902.		
Feb.	28	− ·02
Mar.	10	− ·08
	17	·00
	22	− ·05
Apr.	9	− ·12

W.

1902.		
Sept.	24	+ ·02

84.
4 Urs. Min. B.J.

·308 ± ·149

E.

1902.		
Feb.	28	+ ·07
Mar.	10	+ ·13

W.

1902.		
Sept.	24	+ ·08
Oct.	11	+ ·18

85.
λ Boötis, B.J.

·852 ± ·565

E.

1902.		
Mar.	17	+ ·09
	22	+ ·05
Apr.	4	+ ·04
	17	·00
	26	− ·01

W.

1902.		
June	27	+ ·02
	30	+ ·11
July	1	+ ·03
Aug.	23	+ ·09

86.
θ Boötis, B.J.

·803 ± ·483

E.

1902.		
Mar.	10	·00
	17	+ ·01
	22	− ·03
Apr.	2	·00
	4	+ ·03

W.

1902.		
Aug.	23	+ ·02
Sept.	24	− ·07

87.
ρ Boötis.

·765 ± ·804

W.

1902.		
June	26	·00
	27	− ·06
	30	− ·04
July	1	− ·04

88.
ϵ_2 Boötis.

·680 ± ·859

E.

1902.		
May	1	− ·02
	2	− ·04
	8	− ·05

W.

1902.		
June	26	+
July	1	+

89.
β Urs. Mi

·392 ± ·19

E.

1902.		
Feb.	28	+
Mar.	10	
Apr.	9	

W.

1902.		
Sept.	24	−

90.
β Boötis

·865 ± ·64

W.

1902.		
June	30	−
July	1	−
Aug.	23	−

92.
δ Boötis.

·814 ± ·75

E.

1902.		
Apr.	2	−
May	1	
	2	−
	8	+

93.
μ Boötis, B.J.
·853 ± ·695
E.
1902
Apr. 2 + ·11
May 1 + ·08
2 + ·08
W.
1902.
June 30 + ·04
July 1 + ·06

94.
γ Urs. Min.
·448 ± ·222
E.
1902.
Mar. 10 − ·07
17 − ·07
Apr. 2 − ·06
4 − ·01

95.
ε Drac.
·707 ± ·388
W.
1902.
Oct. 8 − ·05
11 + ·01

96.
β Coronæ, B.J.
·734 ± ·827
1902.
May 1 − ·08
8 − ·09

97.
ν Boötis, B.J.
·865 ± ·643
E.
1902.
May 2 + ·02

98.
α Coronæ.
·665 ± ·867
W.
1902.
June 26 + ·05
27 − ·25
30 + ·04
July 1 + ·02
Aug. 23 ·00

99.
ζ Urs. Min.
·306 ± ·148
E.
1902.
Mar. 22 − ·09
Apr. 2 + ·03
„ 17 − ·14
W.
1902.
Sept. 18 − ·06
Oct. 8 + ·10

100.
θ Drac. B.J.
·713 ± ·395
E.
1902.
Apr. 2 − ·15
4 − ·12
23 − ·07
26 − ·07
May 1 − ·19
8 − ·10

W.
1902.
Oct. 8 − ·02
11 − ·29

101.
19 Urs. Min. B.J.
356 ± ·173
E.
1902.
Mar. 22 + ·08
Apr. 2 + ·01
4 − ·06
17 + ·06
26 + ·02

102.
τ Herc.
·852 ± ·564
E.
1902.
May 1 + ·16
2 + ·04
8 + ·09
W.
1902.
Sept. 24 + ·16
Oct. 8 + ·18
11 + ·19

104.
A Drac. B.J.
·519 ± ·262
E.
1902.
Apr. 2 + ·06
4 + ·08
23 + ·13
26 + ·10
May 8 + ·08
W.
1902.
Sept. 24 + ·07

105.
ζ Herc.
·784 ± ·789
E.
1902.
May 8 + ·05
28 + ·13
W.
1902.
Sept. 16 − ·01
24 + ·05

106.
ε Urs. Min.
·202 ± ·097
E.
1902.
Apr. 26 + ·03
May 8 − ·01
W.
1902.
Sept. 16 + ·06
Nov. 1 + ·09

107.
ε Herc.
·771 ± ·800
E.
1902.
May 20 + ·04
23 + ·03
28 − ·01
W.
1902.
Sept. 16 − ·10

108.
ζ Drac.

·585 ± ·303

W.
1902.
Sept. 18 +·01
Nov. 1 −·01

109.
δ Herc.

·585 ± ·904

W.
1902.
Aug. 23 −·04
Sept. 24 +·02

110.
π Herc.

·848 ± ·708

E.
1902.
May 8 +·09
20 +·03
23 −·02
28 +·11

W.
1902.
Sept. 24 ·00
Oct. 8 −·06
11 +·10

111.
β Drac.

·803 ± ·483

E.
1902.
May 1 +·02
8 ·02

112.
89 Herc.

·631 ± ·884

W.
1902.
Sept. 24 −·08
Oct. 11 +·09

113.
γ Drac.

·812 ± ·494

E.
1902.
May 8 −·01
23 −·01

W.
1902.
Sept. 8 ·00

115.
χ Drac. B.J.

·437 ± ·216

E.
1902.
May 1 −·01
8 −·04

116.
α Lyræ.

·858 ± ·681

E.
1902.
May 23 +·04
28 −·01

W.
1902.
Sept. 8 −·08
18 −·03
24 −·06
Oct. 11 +·01
Nov. 1 −·12

117.
β Lyræ.

·808 ± ·765

E.
1902.
June 26 ·00
27 +·04
July 1 −·02

W.
1902.
Sept. 8 +·02
18 +·03
Oct. 11 −·16

118.
γ Lyræ, B.J.

·798 ± ·776

E.
1902.
June 26 +·05
27 +·05
30 ·00
July 1 −·01

W.
1902.
Sept. 8 +·07
18 +·02
24 −·07
Oct. 11 −·06
Nov. 1 +·11

119.
8 Drac.

·551 ± ·282

E.
1902.
May 8 −·01
23 −·09
28 −·04

W.
1901.
Dec. 27 −·04
1902.
Oct. 20 ·00
21 ·00
30 −·07
(Dec. 15 −·09)

120.
κ Cygni, B.J.

793 ± ·472

E.
1902.
May 20 −[illegible]3
23 +[illegible]5
28 +[illegible]3

W.
1902.
Sept. 16 +[illegible]01
Oct. 20 −[illegible]02
21 −[illegible]3
Nov. 1 −[illegible]3

121.
τ Drac. B.J.

·425 ± ·210

W.
1902
Oct. 20 +·02
21 −·04
30 +·02

Nov. 7 −·04
10 +·02
12 −·02
21 +·05
Dec. 15 +·01)

123.
ε Vulpec.
·562 ± ·913
W.
1902.
Sept. 24 −·06

124.
θ Cygni, B.J.
·827 ± ·515
W.
1902
Sept. 16 +·04
Oct. 20 +·07
21 +·03

125.
Drac. B.J.
·497 ± ·250
E.
1902.
Oct. 20 +·01
23 +·06
28 −·04
W.
1902.
Oct. 20 +·20
21 +·09
30 +·02
Nov. 7 +·16
10 +·09
12 +·03
21 +·08
Dec. 15 +·22)

126.
κ Cygni, B.J.
·323 ± ·156
W.
1902.
Oct. 20 +·15
30 +·10
Nov. 7 +·16
10 +·10
17 +·05

127.
24 Vulpec. B.J.
·558 ± ·913
E.
1902.
Aug. 23 −·19
Sept. 24 −·03

128.
γ Cygni.
·863 ± ·661
W.
1901.
Dec. 27 ·00

129.
73 Drac. B.J.
·390 ± ·192
W.
1902.
Oct. 20 +·06
30 +·03
Nov. 7 −·06
10 −·01
17 +·02
21 +·02
(Dec. 15 −·08)

130.
α Cygni.
·860 ± ·587
E.
1902.
June 26 −·02
27 −·02
30 −·12
July 1 ·00
Aug. 23 +·12
W.
1901.
Dec. 27 +·04

131.
ε Cygni.
·813 ± ·759
E.
1902.
June 30 +·02
July 1 +·04
Aug. 23 +·07

132.
76 Drac. B.J.
·203 ± ·097
E.
1902.
May 20 −·04
23 −·03
28 +·01
W.
1902.
Nov. 17 +·05
21 +·05

133.
32 Vulpec.
·686 ± ·857
W.
1902.
Sept. 16 +·02

134.
γ Cygni, B.J.
·865 ± ·649
E.
1902.
June 26 −·02
27 +·16
30 +·05
July 1 ·00
Aug. 23 −·05
W.
1902.
Oct. 20 −·12
21 +·04
30 +·05
(Dec. 15 −·20)

136.
α Cephei.
·656 ± ·351
E.
1902.
June 27 −·04
30 −·07
July 1 −·04
W.
1902.
Oct. 20 −·08
30 −·12
Nov. 7 −·12
10 −·14
17 −·15
21 −·07
(Dec. 15 −·10)

137.
β Cephei.
·494 ± ·248
1902.
June 26 −·01
27 −·12
30 +·03
July 1 −·05

138.
16 Pegasi.
·607 ± ·894
W.
1902.
Oct. 20 −·07
21 −·04

139.
20 Cephei, B.J.
654 ± ·349
E.
1902.
June 26 −·04
27 +·13
30 ·00
July 1 −·01
W.
1902.
Nov. 17 +·09

140.
ι Pegasi.
·582 ± ·904
W.
1901.
Dec. 27 +·01

141.
π Pegasi B.J.
·800 ± ·774
W.
1902.
Oct. 21 −·07
30 −·12
Nov. 7 −·19
10 +·01
12 −·09
21 −·07
(Dec. 15 +·10)

143.
7 Lacertæ, B.J.
·828 ± ·519
E.
1902.
June 30 +·12
July 1 +·04
Aug. 23 +·04
Sept. 24 +·01
W.
1902.
Nov. 17 ·00
21 +·04
(Dec. 15 +·09)

144.
η Pegasi.
·741 ± ·822
W.
1901.
Dec. 27 +·10
1902.
Oct. 20 −·09
30 +·08
Nov. 7 +·03
10 −·01
12 +·03
Nov. 17 +·09
21 −·08
(Dec. 15 +·12)

146.
μ Pegasi.
·543 ± ·918
W.
1901.
Dec. 27 −·13

147.
ι Cephei, B.J.
·588 ± ·305
1902.
Jan. 29 +·13

148.
β Pegasi, B.J.
·682 ± ·858
E.
1902.
Sept. 8 −·06
24 −·05
W.
1901.
Dec. 27 −·01
1902.
Oct. 30 +·05
Nov. 7 +·10
10 −·05
12 +·01
17 −·02
(Dec. 15 −·09)

149.
π Cephei, B
·384 ± ·18
1902.
June 30 −
July 1 +
Aug. 23 −

150.
Br. 3077 B
·748 ± ·42
1902.
Jan. 29 +

152.
ι Androm. B
·865 ± ·61
1902.
Oct. 8 +

153.
γ Cephei
·331 ± ·16
1902.
June 30 −
July 1 +
Aug. 23 +
W.
1901.
Dec. 27 −

155.
μ Andromed
·855 ± ·6
1902.
Sept. 8 +
18 +
24 −
Oct. 11 +
Nov. 1 −
W
1902.
Dec. 27 +

§ 9. *Conclusion.*

In putting forward these observations I am regretfully aware of their incompleteness. I propose to continue the research with the intention of (i) examining the origin in the hourly changes in z, with a view to their reduction or removal, (ii) finding the latitude, (iii) investigating difference of personality of two observers in different oblique transits, and (iv) forming a catalogue of star places and discovering what, if any, are the systematic differences of places found by the transit circle and almucantar. I do not wish hastily to express an opinion on the merits of the instrument beyond what the foregoing results will evidence, and will only say that in the cases of difficulty that have already arisen I have found it so tractable that I look with considerable confidence to reducing or removing the small anomalies that remain.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

L. LXIII. MAY 8, 1903. No. 7

Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

The President announced that the Council had elected Lady ggins and Miss Agnes M. Clerke Honorary Members of the iety.

Ole Theodor Olsen, F.L.S., F.R.G.S., 116 St. Andrew's Terrace, Grimsby ;
Captain Ernest W. Owens, Local Marine Board, Dock Street, E. ;
Captain B. F. Stevens, Letts Green, Knockholt, Sevenoaks, Kent ; and
Rafel Patxot Jubert, Passeig Bonanova 64, Barcelona, Spain,

balloted for and duly elected Fellows of the Society.

The following were proposed by the Council as Associates ie Society :—

M. G. Bigourdan, Observatoire, Paris ;
Professor G. W. Hough, Director of the Dearborn Observatory, Evanstown, Ill., U.S.A. ;
J. W. Hussey, Lick Observatory, Mount Hamilton, Cal., U.S.A. ; and
Professor Max Wolf, F.R.A.S., Astrophysical Observatory, Königstuhl, Heidelberg, Germany.

The following candidates were proposed for election as lows of the Society, the names of the proposers from personal owledge being appended :—

Rev. E. Goetz, S.J., Director of the Astronomical and Meteorological Observatory, Bulawayo, Rhodesia (proposed by Rev. W. Sidgreaves) ;

A. E. Hodgson, Natal Observatory, Durban, Natal (proposed by Dr. W. J. S. Lockyer);
H. E. Zufur Jung, G.C.B., Military Minister to His Highness the Nizam, Hyderabad, India (proposed by R. Wigglesworth);
Percy Lankester, Highwood House, Kingston Hill, Surrey (proposed by Captain P. Thompson);
Thomas Robson, B.A., Science Teacher, 14 King's Road, Doncaster (proposed by J. A. Barringer); and
Benjamin Spencer Wolfe, M.A., Senior Mathematical Master, Victoria College, Jersey (proposed by Bryan Cookson).

Sixty-six presents were announced as having been received since the last meeting, including, amongst others :—

J. Boccardi, Guide du Calculateur, 2 vols., presented by the author; F. Bidschof, Katalog von 2417 Sternen für 1885·0, presented by the author; Heidelberg, Astrophys. Observatorium, Publikationen, Band 1, presented by the Observatory; J. A. C. Oudemans and J. Bosscha, Galilée et Marius, presented by Professor Oudemans; Astronomischer Jahresbericht, Band 4, 1902, presented by Dr. Wislicenus.

Extract from a Letter from Dr. Th. Albrecht, Vice-Director of the International Geodetic Bureau.

The Central International Geodetic Bureau has just received your letter of April 3, and learns with great interest of the resolution passed by the Council of the Royal Astronomical Society at their meeting on March 13, with regard to the augmentation of the International Latitude Service by a series of observations in the southern hemisphere. The Central Bureau is the more gratified at this decision, since it had proposed in June 1896, seven years before Professor Chandler, that observations should be made on the parallels of Sydney, Cape Town, and Santiago. (See *Verhandlungen der in Oktober* 1900 *in Lausanne abgehaltenen Konferenz der permanenten Kommission der internationalen Erdmessung.*). . .

[The remainder of Dr. Albrecht's letter refers to a printers' error in the proof of Mr. Chandler's letter which was sent to the International Geodetic Bureau, for which Mr. Chandler was in no way responsible, and which is corrected in the copy printed in the *Monthly Notices.*]

Potsdam: 1903 *April* 8.

Note on the Celestial Photographs made at the Yerkes Observatory by Mr. G. W. Ritchey, and recently presented to the Society.

When the photographs of the *Orion* nebula and the *Andromeda* nebula were shown on the screen at the meeting of the Society on March 13 the question was raised whether any selective process of development or printing had been used in order to preserve the detail in the bright central portions while the faint extensions are brought up. In a letter to Mr. Hinks, dated 1903 April 2, Mr. Ritchey has given the following account of his methods of development, with permission to make it known to the Society. This account was the subject of a discussion at the meeting on May 8, and the wish was expressed that it should be printed in the *Monthly Notices*.

"For ten years I have developed all my negatives with Rodinal, a concentrated (one solution) liquid developer prepared after Andresen's formula. According to directions, one part of Rodinal is to be used with thirty parts of water for normal exposures. This works slowly, and gives a rather thin negative—but strong and brilliant, but rich in detail. The directions prescribe Rodinal one part, water forty parts, for undertimed negatives; and Rodinal one part, water twenty parts, for overtimed negatives. In developing astronomical negatives I begin with a very weak solution, Rodinal one part, water 120 parts, and develop for one hour, increasing the strength of the developer gradually every ten minutes, until the proportion becomes Rodinal one part, water sixty parts, for the last ten minutes of the hour. The slow development gives faint detail; the long development gives strength; the slow delicate development, without forcing, keeps the detail fine by avoiding the fogging of the images and coarseness of grain of plate. Double stars, for example, which would appear run together on account of the spreading of the images—were developer of normal strength used—are kept sharply separated. Rodinal allows prolonged development without chemical fog; it is best to use distilled water with it.

"This procedure gives negatives without great contrasts. All plates are backed to prevent halation while being exposed in the telescope.

"But in the case of such objects as the *Orion* and *Andromeda* nebulæ something more than the above is needed if the detail in the bright central parts and the faint extensions are both to be shown on the same positive. One negative is secured precisely as developed by the above method. For transparencies and lantern slides a second negative is exposed in the telescope, developed as above described, and the parts which are so dense that they cannot be printed are reduced locally by

the use of very weak reducing solution. Much time and care are given to this, and an attempt is made to keep the relative brightness of the various parts the same in kind, though not in degree, as in the unreduced negative, which is constantly used for comparison during the process."

On the Verification of the Newtonian Law.

By Ernest W. Brown, F.R.S.

In the *Monthly Notices* for March and June 1897 I gave the results of an attempt to find out the degree of accuracy with which the theoretical values of the mean motions of the lunar perigee and node could be determined with the new data then available. My computations in the lunar theory had proceeded sufficiently far to enable me to give accurately the parts of these motions inclusive of the squares of the eccentricities and inclinations; the remaining parts, due to the direct action of the Sun, were estimated from Delaunay's literal expressions. Owing to the fact that some of Delaunay's higher terms were rather doubtful, that they only included two powers of m at most, and that slow convergence rendered an estimate of the remainders very doubtful, it was expedient to assign possible errors to the results quite large in comparison with the magnitudes of the terms which were estimated. They were set down in the second paper as follows :—

Mean Motions per annum.

	For the Perigee.	For the Node.
Calculated,	$+146\ 434''\cdot6 \pm 1''\cdot8$,	$-69\ 679''\cdot3 \pm 1''\cdot1$;
Hansen,	$+146\ 434''\cdot0$,	$-69\ 676''\cdot8$;
Observed,	$+146\ 435''\cdot6$,	$-69\ 679''\cdot5$.

It was noted that the possible error $\pm 1''\cdot8$ prevented any new discussion in the case of the perigee, but that the smaller possible error $\pm 1''\cdot1$ showed that Hansen's theoretical result for the node was wrong by at least $1''\cdot4$.

A short time ago my calculations in the lunar theory reached a stage which made it possible to include in the theoretical values the terms of the fourth order with respect to the eccentricities, inclination, and ratio of the parallaxes, so far as these produced a sensible effect. Although the final verifications are not yet complete, the results have been tested sufficiently to permit of their publication with confidence in their substantial

accuracy: as far as the solar perturbations are concerned, I do not think that they can be in error by more than two-tenths of a second. It may also be added that the *estimated* corrections, contained in the second of the papers referred to, due to the ratio of the sum of the masses of the Earth and Moon to that of the Sun, have been tested by exact calculation and found to be right.

The Annual Mean Motions now obtained are—

	For the Perigee.	For the Node.
By calculation,	$+146\ 435''{\cdot}5 \pm 0''{\cdot}2$,	$-69\ 679''{\cdot}6 \pm 0''{\cdot}2$;
By observation,	$+146\ 435''{\cdot}6$,	$-69\ 679''{\cdot}5$;

an agreement between theory and observation which was hardly to be expected. The parts due to the Sun's action are now entirely deduced from my calculations, and the parts due to planetary action and the figure of the Earth are the same as given in the first of the papers referred to above, the former being obtained by Hansen and the latter by G. W. Hill. The observed values are also the same as those given there, the values being Hansen's, confirmed by Newcomb.

The chief point of interest in connection with these results is the degree of accuracy of the Newtonian law of gravitation at the distance of the Moon. In his *Astronomical Constants* Professor Newcomb stated that the outstanding differences between theory and observation in the motions of the perihelia of the planets, especially that of *Mercury*, could be well accounted for by assuming the law of gravitation to be $r^{-2-\delta}$ instead of r^{-2} (Hall's hypothesis), where $\delta = {\cdot}0000001574$. This value of δ would cause a correction of $1''{\cdot}4$ in the case of the Moon—almost exactly the difference that Hansen had found. Newcomb adds that the evidence afforded by this agreement in the case of the Moon's perigee is rendered nugatory by the difference $-2''{\cdot}7$ in the case of the node; a difference which the alteration in the law will not explain.

If the new theoretical values of the motions of the Moon's perigee and node are correct, the greatest difference between theory and observation is only $0''{\cdot}3$, making $\delta < {\cdot}00000004$. Such a value for δ is quite insufficient to explain the outstanding deviation in the motion of the perihelion of *Mercury*. It appears, then, that this assumption must be abandoned for the present, or replaced by some other law of variation which will not violate the conditions existing at the distance of the Moon.

Haverford College, Pa., U.S.A.:
1903 *May* 2.

Observations of Stars occulted by the Moon during the Eclipse of 1903 April 11 at the Radcliffe Observatory, Oxford. By Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.

At this observatory the following occultations of stars were observed on the occasion of the lunar eclipse which took place on the night of 1903 April 11. For these observations I employed the 18-inch guiding telescope of the new 24-inch photographic equatorial, Mr. Robinson being stationed at the 10-inch Barclay equatorial. On the 18-inch I was obliged to use the guiding breech-piece, with two slides at right angles to each other, which would have been very convenient with a low-power eyepiece, enabling me to get from one point of the Moon's limb to the other with great facility. But the advantage gained in this way was more than counterbalanced by the fact that the only eye-piece with which we are as yet furnished for this breech-piece is too high (257) for this class of observation, and gives rather a confined field of view.

The times of occultations observed by me were recorded on the chronograph, with which the new instrument is electrically connected, while Mr. Robinson's observations were made by the eye-and-ear method.

As a working list we took the list of stars published by Mr. Crommelin in *The Observatory* magazine for April 1903, p. 186, the times and angles as there given for Greenwich being corrected to adapt them for the Radcliffe Observatory, Oxford, by Chevallier's method (see *Memoirs, R.A.S.*, vol. xix. p. 231).

The clock-errors used in the reductions were found from chronographic transits for my observations, and from eye-and-ear transits for observations by Mr. Robinson. The longitude adopted in the determination of G.M.T. was $5^m\ 2^s{\cdot}6$ W.

The following are the observed times of the occultations:—

No. in Schönfeld Zone −8°.	Obs.	G.M.T. of Observation. Disappearance.	Ref.	Reappearance.	Ref.
		h m s		h m s	
3537	AAR	...		11 10 17·4	(*a*)
3540	AAR	11 13 4·1	(*b*)	...	
	R	4·3	(*c*)	12 26 39·1	(*d*)
3542	AAR	11 33 60·0	(*e*)	12 21 38·2	
	R	58·8 ±	(*r*)	...	
3545	AAR	11 57 41·2	(*g*)	...	
	R	40·9	(*h*)	...	
3543 (fainter ✱)	AAR	12 4 21·8	(*i*)	...	
	R	21·3	(*j*)	...	
3543 (brighter ✱)	AAR	12 9 42·8	(*k*)	...	
	R	42·5	(*l*)	12 40 47·8	(*m*)
3544	AAR	12 47 31·2	(*n*)	...	
	R	31·0		12 55 53·7	(*o*)

Instruments.—Guiding telescope of 24-inch photographic actor, aperture 18 inches. Power used, 257. Observations ɔrded on the chronograph. *Observer* : Dr. Rambaut (AAR). Barclay Equatorial, aperture 10 inches. Wire micrometer : ver used, 88. Observations by the eye-and-ear method. *erver* : Mr. Robinson (R).

Observers' Remarks on the Occultations.

a) Two or three seconds late. (*b*) Good.
c) Instantaneous; good. Limb of Moon invisible.
d) Instantaneous; good. (*e*) Good. Seemed to hang on limb.
f) The star's faint image impinged 2ˢ within the partially illuminated) before disappearing. Observation rather difficult; time uncertain 1ˢ.
g) Instantaneous; good. (*h*) Instantaneous; good.
i) Good. A 10ᵐ star n.p. 3543.
j) Instantaneous; good. Disappeared within limb. (*k*) Good.
(*l*) Instantaneous; good. (*m*) Good; instantaneous.
(*n*) Through clouds. Limb invisible; disappearance instantaneous.
(*o*) Good; instantaneous.
Clouds obscured the Moon after 12ʰ 56ᵐ G.M.T.

General Remarks on the Eclipse by Mr. Robinson.

10ʰ 48ᵐ G.M.T. Shadow very dense and of a smoky-brown t. The limb in eclipse was invisible.

11ʰ 45ᵐ G.M.T. The shadow less dense now, rendering the on's entire periphery visible.

When the eclipse had well advanced, the Earth's shadow was erved, both in the 2·7-inch "finder" and in the 10-inch, to e a distinct penumbral fringe of a uniform width of about 2′. s band was of a slaty colour.

In this connection the following remarks of a correspondent Mr. Robinson's (Mr. Boden, of Ilkley) may be of interest :—

"Had a good visual observation of the recent eclipse, the ather being unusually propitious, and was quite delighted h the beauteous fringe of *sky-slate* shade seen in the telescope wer about 60, lunar disc nearly filling the field) bordering the bra during the *greater* phases, but which disappeared giving ce to a border of indistinct Indian-ink hue during an interval m just before to just after semi-eclipse. Did you notice this utiful coloured penumbra at all in your larger instruments?"

Radcliffe Observatory, Oxford:
1903 *May* 6.

Observation of the Partial Eclipse of the Moon, 1903 April 11. By E. M. Antoniadi.

The weather was fine here on the night of April 11, so that the observations of the eclipse were made under favourable circumstances, the instrument used being a 3-inch achromatic, power 35.

Soon after first contact with the umbra it became evident that a "black eclipse" was developing, the shadow being so dark as to utterly blot out the limb and all topographical details of the lunar surface. As usual, however, the edge of the umbra was transparent: all along a zone extending 3′ from the border inwards, the shadow was of a diaphanous ash-grey colour, in which tinges of green, blue, and violet were alternately and repeatedly suspected.

It was only towards midnight, G.M.T., that by sweeping with the telescope right and left of the Moon, in order to gain contrast, the whole body of our satellite was seen projected as a brownish-black disc on the scarcely darker background of the sky. But to the unaided eye the eclipsed portion remained invisible.

This is the only instance, since 1887, in which I could not see the shaded limb without optical assistance. On 1891 November 15 and 1892 May 11 the colour of the shadow was of a very decided coppery red, brightening to a beautiful roseate hue near the centre of obscuration; and a comparison of these, and other impressions on past eclipses, with the recent "black eclipse" shows how the shadow can vary in colour from rose to black, and how great an interest attaches to the observation of these phenomena.

74 *Rue Jouffroy, Paris:*
1903 *May* 6.

A Possible Cause of the Moon's Obscurity on April 11. By the Rev. S. J. Johnson, M.A.

The ordinary course of an immersion of the Moon in the Earth's shadow is so uniform as to gradations of colour and other matters that it would be useless to occupy space concerning it. On the late occasion, however, the blackness of the Moon's surface was of such an intense character as only seems to have been noticed twice in England in the last century, viz. in 1816 and 1884, and once, in Tasmania, in 1885.

As the curved shadow advanced the appearance was, as usual, that of a dark bar across the S.E. portion of the Moon.

At 11.50, when the whole of the Mare Crisium had just become immersed in the shadow, this was the first and only object I was able to make out in the telescope, and it disappeared in a few minutes. A rim of light greenish-grey extended inwards 4′ from the enlightened crescent. To the naked eye the small bright crescent gave one the impression of being much brighter than it really was, probably owing to irradiation. At 12.0 the whole globe of our satellite could be discerned in the telescope, appearing of a dull faint brown colour. At $12^h\ 10^m\ 52^s$ a faint star, probably B.D. −8°, 3543, disappeared nearly at the lowest point of the disc, and $12^h\ 22^m\ 42^s$ may be taken as the time of emergence of a star, probably B.D. −8°, 3540. At the time of greatest phase, 12.13, and during the retreat of the umbra the eclipsed part of the Moon's disc was entirely of a blackish grey, not a trace of detail being visible.

The usually received explanation of this is the state of the several strata of the atmosphere with regard to transparency or with regard to saturation. On the other hand, if we take the two instances seen in our own land in the last century, 1816 was one of the wettest summers on record, and the eclipse of 1884 October 4 took place after a remarkably fine and dry summer and autumn. They happened, therefore, under directly contrary circumstances as regards meteorological conditions. The eclipse of 1884 taking place a year or so after the Krakatoa explosion, and the late one having happened after the West Indian eruption, it is difficult not to connect the two in some way as cause and effect.

If we go backwards to former occasions of abnormal darkness of the eclipsed Moon, such instances seem to have taken place a year or two after volcanic disturbances.

The eclipse of 1816 June 10 was two years after the eruptions of Mayon (Philippine Islands) mentioned by Arago. The following, however, from the *American Almanack* for 1833, p. 70, is perhaps more to the point:—

"1814 July 3 and 4. Great fall of black dust in Canada with appearance of fire. This event was similar to that of 472.—*Phil. Mag.* vol. xliv.

"1815. Towards the end of September. The sea south of India was covered to a great extent with dust.—*Phil. Mag.*, 1816 July.

"1816 April 15. Red snow in different parts of the northern region of Italy."—*Giornale di Fiscia, &c.*, t. 1, 1818, p. 473."

The previous instance of a disappearance of the Moon occurred on 1761 May 18, observed by Wargentin at Stockholm, who says that "not the slightest trace of any portion of the lunar disc could be discerned either with the naked eye or with the telescope." This took place after a noted volcanic disturbance. Arago, *Popular Astronomy*, vol. ii., art. The Earth, p. 97, says: "The catastrophe which gave birth to the volcano of Jorullo (Mexico) is perhaps, says M. Humboldt, one of the most extra-

ordinary physical revolutions which the annals of our planet offer. In the midst of a continent, at a distance of thirty-six leagues from the sea coast and forty-two leagues from any active volcano, a tract of land of about twelve square kilometres was upheaved in the form of a bladder during the night of 1759 September 28–29. In the centre of a multitude of ignited cones there suddenly arose six mountains of from 1,300 to 1,600 feet above the original level of the neighbouring plains. The principal mountain, the volcano of Jorullo, has an altitude of 1,696 feet. Its eruptions continued without intermission down to the month of 1760 February."

We may well suppose that the volcanic dust in so similar an eruption to those of Krakatoa and Mount Pelée had travelled to the atmosphere of the Scandinavian peninsula by the time of the eclipse.

The previous instance seems to have been in 1642 April mentioned by Wendelinus. Arago remarks: "The Tunguragua made an explosion in 1641," also (speaking of the Philippine Islands), "Aringuay made an eruption in 1641."

As to the cases of 1620 and 1601, I have not hitherto noticed any account of previous volcanic action, but we may well believe such to have taken place, as it cannot be expected that all the eruptions in the Pacific were recorded at that date.

Wendelinus (*Eclipses Lunares*) speaks of another case of darkness of the eclipsed Moon, "a matter that Tycho has left in writing about the eclipse of 1588," and Arago says, "The two peaks, very close to each other, called the Fuegos de Guatemala, experienced terrible eruptions in the year 1586.

Something may therefore be said in support of the conjecture that the presence of volcanic dust in the upper regions of the air may be connected with the obscurity of the Moon's surface on the occasions referred to.

Melplash Vicarage, Bridport: April 18.

Eclipse of the Moon of 1903 *April* 11, *observed at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

In addition to observation of occultations, preparations were made to observe the times of transit of the first and second limbs of the Moon in order to compare the diameters as found from bright and dark limbs respectively. For this purpose additional wires were inserted in the Merz refractor (aperture 13 in.) and in the guiding telescope (aperture 10 in.) of the astrographic

rial. Owing to clouds only a few observations were ed, the results of which are given in the following table:—

Sidereal Time of the Passage of the Moon's Diameter.

	Instrument.	Aperture	Duration 1L and 2L Bright.	No. of transits.	Total No. of wires.	Duration 1L Bright. 2L Eclipsed.	No. of transits.	Total No. of wires.
		in.	m s			m s		
son ...	Merz Refractor.	13	2 11·11	1	7			
llis ...	Astrographic Guiding Telescope.	10	11·44	2	14			
mmelin	Sheepshanks Equatorial.	6·8	11·16	8	20	2 11·18	2	10

tabular time of transit given in the *Nautical Almanac* is ·19.

e eclipsed limb was extremely faint, and not considered able by Mr. Dyson and Mr. Hollis.

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s of Micrometric Measures of Double Stars made with the -inch Refractor at the Royal Observatory, Greenwich, in year 1902.

(*Communicated by the Astronomer Royal.*)

e measures were made with a bifilar position micrometer on -inch refractor, focal length 28 feet. The power generally vas 670, but when the definition permitted a power of 1120 nployed for observing very close pairs. A blue glass shade nployed to diminish the light and irradiation when bright were observed. The observations were made in variously ed fields or in a dark field with illuminated wires. The s in the last column are those of the observers, viz.—

L.	Mr. Lewis.	W. B.	Mr. Bowyer.
B.	Mr. Bryant.	H. F.	Mr. Furner.

etric Observations of Double Stars at the Royal Observatory, Greenwich.

s Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1902.	Obs.
	h m	° ′	°	″				
...	0 2	86 23	92·9	0·59	1	8·7 9·3	·923	L.
...	0 2	58 53	356·1	1·18	1	7·0 12·5	·014	L.
...	0 8	63 35	43·9	0·57	2	6·5 8·0	·466	L.
...	0 10	69 3	187·5	1·57	2	7·5 10·9	·469	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1902.	Obs.
	h m	° ′	°	″				
β 1015 ...	0 16	78 14	117·7	0·41	1	8·4 8·6	·865	W.B.
			124·4	0·49	1	...	·923	L.
β 1093 ...	0 16	73 36	49·6	0·38	1	7·5 8·5	·884	L.
β 1225 ...	0 22	69 27	188·3	1·29	1	8·1 11·8	·923	L.
OΣ 12 ...	0 26	36 8	149·2	0·50	2	5·0 6·0	·431	B.
Σ 60 ...	0 43	32 43	225·9	5·44	1	4·0 7·6	·014	L.
			223·3	5·61	1	...	·079	B.
β 495 ...	0 43	71 52	223·3	0·54	3	8·0 8·2	·854	W.B.
OΣ 20 ...	0 49	71 22	317·0	0·42	1	5·9 7·0	·887	W.B.
Σ 73 ...	0 50	66 55	22·6	1·08	2	6·2 6·8	·827	W.B.
			21·0	1·10	1	...	·786	H.F.
β 1099 ...	0 51	30 11	320·8	0·19	1	6·1 6·5	·783	B.
β 302 ...	0 53	69 8	101·2	0·51	1	6·7 8·0	·887	W.B.
β 235 ...	1 5	39 31	96·1	0·83	2	7·2 7·3	·831	B.
Σ 113 ...	1 15	91 2	352·0	1·30	1	6·2 7·2	·953	H.F.
			356·4	1·25	1	...	·991	W.B.
β 507 ...	1 30	63 44	150·1	2·02	1	8·0 11·0	·167	L.
Σ 138 ...	1 31	82 52	38·5	1·46	1	7·3 7·3	·953	H.F.
β 1016 ...	1 44	57 25	211·5	0·89	1	8·5 8·5	·167	L.
Ho. 311 ...	1 46	65 50	189·8	0·30	1	7·5 7·7	·167	L.
			181·4	0·40	1	...	·887	W.B.
Σ 183 ...	1 49	61 41	162·0	5·31	1	7·5 8·2	·887	W.B.
OΣ 38 ...	1 58	48 10	116·8	0·44	2	5·0 6·2	·039	L.
			117·3	0·36	3	...	·118	B.
Ho. 497 ...	2 7	50 7	66·1	0·65	1	8·2 9·0	·167	L.
Σ 228 ...	2 8	42 59	90·6	0·52	1	6·7 7·6	·115	L.
			88·6	0·49	1	...	·119	B.
Σ 236 ...	2 11	38 0	259·1	1·11	1	8·5 9·3	·167	L.
OΣ 42 ...	2 27	38 8	141·8	0·14	2	7·0 7·5	·137	B.
			single				·167	L.
Σ 305 ...	2 42	71 2	315·7	3·02	3	7·3 8·2	·621	W.B.
			320·8	2·99	1	...	·786	H.F.
β 524 ...	2 47	52 5	208·4	0·24	2	5·5 6·5	·115	L.
			180·4	0·10	1	...	·079	B.
Σ 333 ...	2 53	69 4	206·8	1·13	1	5·7 6·0	·014	L.
			199·7	1·20	2	...	·529	W.B.
			205·5	1·36	1	...	·786	H.F.
β 525 ...	2 53	52 31	136·1	0·22	2	7·5 7·5	·091	L.
			130·6	0·22	2	...	·137	B.

n's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1900.	Obs.
3 ...	2 53	66 16	342·7	0·30	1	7·7 7·8	·014	L.
...A.B.	3 0	65 8	268·6	0·54	1	6·0 6·0	·014	L.
$\frac{A.B.}{2}$C.			358·7	5·37	1	...	·014	L.
) ...	3 4	68 39	159·9	0·53	2	8·4 8·4	·102	L.
			157·7	0·56	2	...	·137	B.
...	3 11	51 44	233·3	0·54	1	7·2 8·0	·110	W.B.
...	3 29	58 39	50·5	0·60	2	7·0 7·0	·137	B.
...	3 29	65 52	10·5	...	1	6·6 6·7	·014	L.
			359·4	0·27	2	...	·137	B.
...	3 33	56 10	90·4	2·63	2	7·3 7·3	·088	W.B.
			93·5	2·35	1	...	·953	H.F.
...	3 38	58 2	49·7	0·90	2	3·8 8·5	·137	B.
...	3 38	58 9	15·7	0·58	3	8·5 9·0	·147	L.
			358·1	0·52	1	...	·159	B.
...	3 40	66 6	292·3	0·15	1	8·3 8·9	·159	B.
4 ...	3 42	67 56	263·1	0·46	1	8·1 8·3	·110	W.B.
			270·7	0 48	1	...	·159	B.
) ...	3 45	49 30	137·2	0·62	1	7·5 8·0	·159	B.
1 ...	4 1	52 12	131·4	2·00	1	8·5 10·2	·110	W.B.
...	4 10	58 34	135·0	0·28	1	7·0 7·5	·159	B.
) ...	4 17	47 46	178·0	0·45	1	6·5 7·0	·159	B.
...	4 18	78 51	324·4	1·49	2	6·7 8·2	·072	W.B.
) ...	4 31	70 27	60·8	0·37	2	7·5 7·5	·554	W.B.
...	4 31	70 44	320·2	1·87	1	8·5 9·0	·035	L.
			321·5	1·77	2	...	·529	W.B.
...	4 32	63 18	201·2	3·86	1	6·5 6·5	·035	L.
			201·4	3·73	2	...	·529	W.B.
			201·4	3·57	1	...	·953	H.F.
...	4 46	79 6	69·6	0·33	1	7·5 7·5	·014	L.
			78·3	0·30	1	...	·192	B.
...	5 2	81 39	169·6	0·74	1	5·5 7·0	·997	W.B.
B.C.	5 10	98 18	158·4	0·44	1	8·0 8·0	·006	L.
A.B.			199·7	10·06	1	1·0 8·0	·006	L.
...	5 16	56 17	248·5	0·83	2	8·8 9·8	·219	L.
A.B.	5 16	56 41	189·2	0·96	1	9·0 10·0	·271	L.
A.C.			114·3	9·98	1	9·0 13·5	·271	L.
A.D.			329·0	10·32	1	9·0 12·2	·271	L.
A.E.			203·2	15·59	1	9·0 13·5	·271	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1902.	Obs.
	h m	° ′	°	″				
Dawes 5 ...	5 19	92 29	77·9	0·86	1	3·5 5·5	·192	B.
Σ 719 A.B.	5 24	60 32	326·3	1·00	1	7·0 8·5	·020	L.
A.C.			348·7	15·20	1	7·0 8·9	·020	L.
Σ 749 ...	5 31	63 8	174·4	0·98	1	7·1 7·2	·271	B.
			169·0	0·81	2	...	·532	W.B.
β 1240 ...	5 32	59 34	330·0	0·24	3	5·6 6·0	·188	B.
β 1007 ...	5 36	73 31	254·2	0·24	2	6·0 6·2	·203	B.
OΣ 118 ...	5 42	69 10	306·1	0·60	1	8·0 8·8	·997	W.B.
β 560 ...	5 43	60 18	149·8	0·69	1	8·0 8·5	·233	L.
Σ 779 ...	5 45	51 28	180·9	0·74	1	7·2 8·3	·266	L.
Aitken 56 ...	6 7	60 56	56·5	1·18	1	8·1 11·8	·233	L.
β 895 A.B.	6 14	61 31	177·7	0·38	1	7·5 7·5	·271	L.
Σ 888 A.C.			249·9	3·04	1	7·5 9·5	·271	L.
Σ 899 ...	6 17	72 22	17·8	2·24	1	7·0 8·0	·997	W.B.
Σ 932 ...	6 29	75 10	325·6	2·07	1	8·2 8·3	·997	W.B.
Σ 948 ...	6 37	30 28	118·7	1·57	1	5·2 6·1	·290	B.
Σ 963 ...	6 44	30 26	76·7	0·44	1	5·9 7·1	·290	B.
OΣ 160 ...	6 48	68 43	175·7	1·22	1	6·8 9·8	·997	W.B.
Σ 1037 ...	7 7	62 35	303·3	0·87	1	7·0 7·1	·192	B.
			300·0	0·75	1	...	·216	L.
			297·2	0·79	2	...	·601	W.B.
β 1023 ...	7 9	63 56	294·4	0·30	2	8·4 8·5	·141	B.
Σ 1110 ...	7 28	57 53	225·2	5·42	1	2·7 3·7	·205	W.B.
			223·0	5·68	1	...	·266	L.
			225·2	5·63	1	...	·301	B.
OΣ 175 ...	7 29	58 50	325·6	0·64	2	6·0 6·6	·208	B.
			325·3	0·48	1	...	·205	W.B.
			325·7	0·54	1	...	·266	L.
Σ 1126 ...	7 35	84 32	144·0	1·12	1	7·0 7·0	·211	L.
Procyon ...	7 35	84 28	344·9	5·39	2	1 10	·214	L.
OΣ 177 ...	7 35	52 19	116·1	0·58	1	7·5 8·5	·115	B.
			130·3	0·54	1	...	·359	L.
OΣ 182 ...	7 47	86 22	35·3	0·88	1	7·0 7·5	·216	L.
OΣ 185 ...	7 52	88 36	30·0	0·46	1	6·8 7·0	·216	L.
Σ 1175 ...	7 57	85 34	225·5	1·78	1	7·8 9·7	·216	L.
β 581 A.B.	7 59	77 25	294·4	0·48	3	8·5 8·6	·198	L.
A.C.			198·9	4·88	2	8·5 11·0	·192	L.
Σ 1186 ...	8 3	62 13	227·2	3·50	1	7·1 10·4	·348	L.

ar's	Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1900.	Obs.
7	...	8 3	57 28	44·5	1·88	1	7·1 8·0	·329	W.B.
6	A.B.	8 6	72 3	357·5	1·20	2	5·0 5·7	·256	W.B.
				362·6	1·07	1	...	·301	B.
	A.C.			112·5	5·49	2	5·0 6·5	·256	W.B.
				112·2	5·19	1	...	·301	B.
	B.C.			126·0	5·86	2	5·7 6·5	·256	W.B.
				123·5	5·68	1	...	·301	B.
3	A.C.	8 41	83 13	234·5	3·47	2	3·5 7·7	·214	L.
				232·3	3·34	1	...	·307	W.B.
'3...	A.B.	8 41	83 13	357·5	—	1	3·8 6·0	·167	L.*
				36·7	—	1	...	·216	L.*
				25·9	—	1	...	·266	L.*
				28·7	—	1	...	·320	L.*
				280·0	0·10	1	...	·301	B.
ıtin	...	8 46	81 17	343·7	0·70	1	7·5 9·5	·320	L.
ıı	...	9 12	61 0	22·6	0·61	2	7·5 7·8	·256	W.B.
				21·6	0·76	3	...	·275	L.
n 221	...	9 13	59 50	290·1	0·39	1	8·7 8·8	·359	L.
3	...	9 13	68 47	310·9	0·55	1	8·0 8·5	·205	W.B.
				304·1	0·44	1	...	·320	L.
ıı	...	9 18	61 39	223·4	1·35	1	7·5 9·0	·285	L.
				219·9	1·54	1	...	·348	H.F.
;6	...	9 23	80 27	111·9	0·68	1	6·2 7·0	·214	B.
;8	...	9 45	35 28	108·6	0·30	2	5·0 5·6	·345	B.
5	...	9 48	97 38	76·1	0·33	1	5·5 5·7	·214	B.
	...	10 9	71 33	8·1	1·38	2	8·0 8·5	·315	L.
18°·2335				6·0	1·44	1	...	·329	W.B.
15	...	10 11	71 45	200·5	0·86	1	7·0 7·2	·214	B.
				207·0	0·64	2	...	·291	W.B.
				207·1	0·91	3	...	·297	L.
14	...	10 14	69 39	114·8	3·62	2	2·0 3·5	·277	W.B.
				115·7	3·81	3	...	·293	L.
16	...	10 15	83 4	179·4	0·79	1	7·8 8·3	·214	B.
16	...	10 17	74 9	108·2	1·14	1	7·0 10·5	·309	L.
19	...	10 20	64 53	254·6	0·92	2	8·3 8·3	·340	W.B.
17	...	10 21	72 16	152·2	0·67	1	7·3 7·8	·214	B.
				157·5	0·69	1	...	·259	W.B.

* ≡ 1273 A.B. See note at end of measures.

Star's Name.	R.A. 1900.	N.P.D. 1900	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1902.	Obs.
	h m	° ′	°	″				
Σ 1439 ...	10 25	68 41	115·5	1·68	1	8·0 8·5	·307	W.B.
β 1074 ...	10 30	43 41	203·3	—	1	6·4 11·2	·359	L.
Σ 1457 ...	10 34	83 45	313·3	1·41	1	7·4 8·4	·307	W.B.
OΣ 224 ...	10 34	80 38	304·5	0·37	1	7·2 9·2	·309	L.
OΣ 225 ...	10 35	70 14	250·9	0·69	1	7·5 11·2	·309	L.
OΣ 228 ...	10 42	66 54	184·0	0·57	1	7·2 8·1	·350	W.B.
OΣ 229 ...	10 42	48 21	322·3	0·78	1	6·7 7·1	·359	L.
Σ 1487 ...	10 50	64 43	107·3	6·47	1	5·0 7·0	·307	W.B.
Hough 47 ...	10 58	53 47	329·9	0·76	1	9 9	·359	L.
„ 378 ...	10 59	51 2	225·1	0·40	1	8·0 8·1	·359	L.
Σ 1517 ...	11 8	69 19	276·2	0·39	2	7·3 7·3	·371	W.B.
Σ 1523 ...	11 13	57 54	146·1	2·46	2	4·0 4·9	·258	B.
			144·0	2·27	1	...	·350	W.B.
Σ 1527 ...	11 14	75 11	16·5	3·38	1	6·9 8·1	·304	L.
Σ 1534 ...	11 17	71 15	330·6	5·33	1	8·0 11·2	·304	L.
Σ 1536 ...	11 19	78 55	56·3	2·42	2	3·9 7·1	·322	L.
			50·8	2·27	1	...	·397	H.F.
			51·9	2·21	1	...	·397	W.B.
Lalande 21846 ...	11 24	58 59	11·5	0·99	2	7 11	·354	L.
OΣ 234 ...	11 25	48 10	146·5	0·30	1	7·0 7·4	·350	W.B.
Σ 1555 ...	11 31	61 40	349·5	0·35	1	6·4 6·8	·214	B.
			352·4	0·48	2	...	·329	W.B.
			350·1	0·36	1	...	·345	L.
OΣ 237 ...	11 34	48 18	268·8	1·30	1	7·4 9·0	·350	W.B.
β 603 ...	11 44	75 10	320·3	0·84	1	6·4 10·2	·309	L.
Σ 1606 ...	12 6	49 33	327·4	1·12	1	6·3 7·0	·214	B.
			328·1	1·04	1	...	·350	W.B.
Σ 1639 ...	12 20	63 52	354·8	0·33	2	6·7 7·9	·315	L.
			357·5	0·31	1	...	·397	W.B.
Σ 1643 ...	12 22	62 25	39·3	2·15	2	8·4 8·7	·317	L.
			36·8	2·15	1	...	·307	W.B.
Σ 1647 ...	12 26	79 44	40·9	1·30	2	7·5 7·8	·350	L.
			38·1	1·30	1	...	·397	H.F.
Σ 1658 ...	12 30	82 0	359·0	2·38	1	8·0 9·8	·304	L.
Σ 1663 ...	12 32	68 15	104·3	0·74	2	7·8 8·7	·352	W.B.
			106·1	0·90	1	...	·397	H.F.
Σ 1670 ...	12 37	90 54	328·1	5·75	2	3·0 3·0	·404	W.B.

ar's	Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1902.	Obs.
7	...	12 48	68 13	84·8	1·03	1	5·0 7·8	·320	L.
				87·5	1·21	2	...	·373	H.F.
				87·1	1·18	2	...	·395	W.B.
	...	12 57	71 5	293·8	1·92	1	6·5 8·5	·320	L.
1	...	12 58	75 59	350·3	0·93	1	8·5 9·0	·320	L.
0	...	13 3	62 31	119·0	0·63	2	7·9 8·3	·307	L.
3	...	13 5	71 57	194·2	0·40	2	6·0 6·0	·252	B.
				193·4	0·43	2	...	·312	L.
				192·3	0·35	1	...	·392	W.B.
1	...	13 7	57 23	343·3	1·40	2	6·9 7·4	·427	W.B.
	...	13 12	72 27	111·9	2·84	2	7·1 10·2	·334	L.
				113·1	2·84	1	...	·348	H.F.
de	24673	13 12	72 7	127·3	4·56	2	8·0 8·5	·334	L.
4	...	13 16	86 32	189·3	0·92	1	7·2 7·9	·304	L.
2	...	13 19	88 5	350·5	1·17	1	7·4 7·9	·304	L.
1	260 ...	13 19	60 15	328·7	0·58	1	8·3 9·5	·320	L.
5	...	13 23	73 47	343·6	1·53	1	7·3 7·8	·304	L.
				337·1	1·64	1	...	·416	W.B.
9	...	13 28	54 34	217·9	0·29	2	6·5 7·0	·449	W.B.
3	...	13 33	53 13	131·3	1·20	1	5·7 7·6	·290	B.
				127·4	1·38	2	...	·449	W.B.
	...	13 35	78 45	246·5	0·27	2	6·3 6·5	·335	L.
	...	13 45	62 31	284·1	1·30	2	7·2 7·5	·390	W.B.
				285·0	1·16	2	...	·411	H.F.
	...	13 59	81 2	Round	...	1	8·2 8·3	·309	L.
				Round	...	1	...	·321	L.
	...	14 6	62 56	81·5	2·65	2	8·0 9·0	·407	W.B.
3	...	14 8	45 21	93·5	0·26	2	7·5 7·5	·487	B.
	...	14 10	86 24	358·8	1·19	1	7·9 8·0	·424	H.F.
	...	14 17	41 2	118·2	0·29	1	7·1 7·2	·728	B.
	...	14 19	81 6	128·7	...	1	5·5 6·8	·419	L.*
	...	14 36	75 51	151·5	0·54	1	3·5 3·9	·266	B.g.†
				149·6	0·32	2	...	·343	L.
				150·9	0·33	4	...	·436	B.
	...	14 36	58 17	14·6	1·28	3	7·7 8·2	·435	W.B.
	...	14 41	62 30	328·6	2·38	1	3·0 6·3	·424	H.F.
				326·6	2·73	2	...	·452	W.B.

* 1835. Distance not greater than 0″·15. † M. Bigourdan.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1902.	Obs.
	h m	° ′	°	″				
Σ 1879 ...	14 41	79 55	132·7	0·46	1	7·8 8·8	·399	L.
			126·0	0·72	1	...	·460	W.B.
OΣ 285 ...	14 42	47 11	124·9	0·27	3	7·1 7·6	·567	B.
			124·6	0·28	1	...	·501	L.
Σ 1883 ...	14 44	83 37	250·0	0·46	1	7·0 7·0	·460	W.B.
			239·3	0·47	2	...	·509	B.
OΣ 287 ...	14 48	44 40	319·3	0·87	3	7·5 7·6	·567	B.
β 31 A.B. ...	14 48	70 51	199·2	1·54	1	8·4 9·7	·501	L.
A.C. ...			163·3	9·13	1	8·4 12·2	·501	L.
OΣ 288 ...	14 49	73 53	189·3	1·45	1	6·4 7·1	·424	H.F.
			191·1	1·58	3	...	·464	W.B.
			189·7	1·46	1	...	·501	L.
β 348 ...	14 56	89 45	114·4	0·42	1	6·0 6·8	·542	B.
Σ 1908 ...	15 1	55 7	141·5	1·39	2	8·2 9·2	·496	W.B.
Σ 1932 ...	15 14	62 48	152·6	0·80	2	5·6 6·1	·438	B.
			149·6	0·65	1	...	·460	W.B.
Σ 1937 ...	15 19	59 21	10·9	0·77	1	5·2 5·7	·320	L.
			9·9	0·78	2	...	·438	B.
			14·3	0·68	1	...	·460	W.B.
Σ 1938 ...	15 20	52 18	70·8	1·11	2	6·7 7·3	·487	B.
			73·7	1·06	2	...	·534	W.B.
Σ 1954 ...	15 30	79 7	185·8	3·53	2	3·0 4·0	·501	H.F.
			185·3	3·55	1	...	·424	L.
			181·1	3·59	1	...	·531	W.B.
Σ 1957 ...	15 31	76 44	153·3	1·23	2	7·9 9·6	·499	W.B.
OΣ 298 ...	15 32	49 52	184·5	1·23	1	7·0 7·3	·501	L.
			182·8	1·03	2	...	·613	B.
β 619 ...	15 38	76 1	1·4	0·42	1	6·5 7·0	·465	W.B.
			5·6	0·51	4	...	·479	B.
Σ 1967	15 38	63 23	120·1	0·58	2	4·0 7·0	·438	B.
			116·4	0·34	2	...	·463	W.B.
β 621	15 46	45 8	58·8	0·48	1	7·5 8·0	·728	B.
OΣ 303	15 56	76 27	145·6	0·89	2	7·4 7·9	·449	B.
			138·2	0·83	3	...	·473	W.B.
			141·6	0·72	1	...	·479	L.
Σ 2021	16 8	76 12	331·9	3·77	2	6·7 6·9	·412	W.B.
			337·4	3·45	1	...	·578	H.F.
β 951	16 19	56 23	46·9	0·84	1	8·2 8·7	·537	W.B.
			52·6	0·89	1	...	·638	L.

...'s Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1902.	Obs.
	h m	° ′	°	″				
... ...	16 25	71 23	92·1	1·61	3	7·5 7·5	·482	W.B.
			93·5	1·63	1	...	·578	H.F.
... ...	16 26	87 48	60·2	1·22	2	4·0 6·1	·447	L.
			56·5	1·48	1	...	·515	W.B.
			51·8	1·24	1	...	·578	H.F.
... ...	16 26	96 49	32·2	0·49	3	7·7 7·7	·476	B.
... ...	16 38	58 13	216·0	1·00	3	3·0 6·5	·481	L.
			215·0	0·97	5	...	·589	B.
			219·0	1·11	2	...	·596	W.B.
... ...	16 39	48 37	305·0	1·16	1	7·5 8·0	·498	B.
			304·5	0·99	1	...	·633	L.
... ...	16 41	46 20	308·1	0·57	2	8·2 8·6	·636	L.
...	16 46	88 37	152·1	0·71	1	6·2 8·1	·515	W.B.
... ...	16 46	80 25	295·5	0·30	1	6·7 8·4	·512	L.
... ...	16 48	61 10	339·4	0·27	3	6·5 8·0	·549	L.
			338·8	0·39	1	...	·537	W.B.
... ...	16 48	57 59	308·3	1·47	1	8·4 8·9	·633	L.
... ...	16 54	85 53	98·2	1·35	2	8·5 8·5	·556	L.
			97·3	1·27	2	...	·607	H.F.
160 ...	16 52	79 36	194·0	0·62	1	8·9 9·2	·512	L.
... ...	16 57	81 24	104·1	1·37	2	6·2 7·4	·493	L.
			158·8	1·36	2	...	·518	W.B.
			164·9	1·29	1	...	·578	H.F.
... ...	17 1	61 46	240·8	8·14	1	6·4 9·2	·474	L.
			242·2	8·07	1	...	·493	W.B.
			244·1	8·26	1	...	·635	H.F.
... ...	17 1	79 19	294·7	1·15	3	8·5 9·4	·503	L.
... ...	17 1	89 13	14·4	1·11	1	8·2 9·2	·512	L.
... ...	17 3	35 24	143·5	2·22	2	5·0 5·1	·682	H.F.
... ...	17 5	105 36	251·5	0·33	3	3·4 3·9	·473	B.
... ...	17 10	75 30	113·1	4·74	2	3·0 6·1	·503	W.B.
			114·8	4·58	1	...	·523	L.
			112·0	4·65	2	...	·604	H.F.
... ...	17 11	65 3	192·1	14·71	3	3·0 8·1	·545	L.
			191·1	14·44	2	...	·575	W.B.
... ...	17 12	63 18	43·6	0·43	2	8·3 8·9	·571	L.
... ...	17 12	75 12	8·7	1·40	1	7·8 12·2	·523	L.
... ...	17 21	59 9	75·7	2·23	1	9·4 9·5	·638	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1902.	Obs.
	h m	° ′	°	″					
Σ 2173	17 25	90 59	328·2	0·91	3	5·8	6·1	·473	B.
OΣ 331 ...	17 27	87 7	333·4	1·09	1	7·5	9·0	·570	W.B.
β 631	17 35	90 36	58·7	0·30	3	7·5	7·6	·473	B.
β 1251	17 37	74 0	63·7	1·42	1	6·0	11·5	·501	L.
Σ 2205	17 40	72 14	307·2	1·98	1	8·3	8·7	·474	L.
			306·1	2·03	2	...		·538	W.B.
Σ 2214 A.B....	17 40	46 13	214·7	19·51	1	8·5	8·8	·685	H.F.
B.C.	...		146·7	1·30	1	8·8	10·3	·685	H.F.
Σ 2215	17 41	72 15	292·7	1·12	1	5·9	7·9	·474	L.
			289·5	0·80	2	...		·534	W.B.
A.C. 7	17 43	62 13	63·3	1·54	1	9·5	11·0	·671	L.
OΣ 337	17 46	82 44	96·9	0·27	3	7·5	8·0	·503	B.
OΣ 338	17 47	74 39	14·0	0·81	3	6·5	7·0	·505	B.
			19·1	0·53	1	...		·537	W.B.
			15·3	0·67	1	...		·616	L.
*	17 48	74 28	292·7	2·18	1	9·0	9·5	·671	L.
Aitken 234 ...	17 49	64 23	32·0	0·54	2	8·8	9·1	·668	L.
„ 235 ...	17 49	64 59	61·0	0·26	2	7·9	8·1	·668	L.
A.C. 9	17 50	60 10	53·5	1·30	1	8·4	8·7	·537	W.B.
Σ 2272... ...	18 0	87 28	212·2	1·66	9	4·1	6·1	·551	W.B.
OΣ 534 ...	18 1	78 34	274·8	2 12	1	7·5	7·5	·706	B.
OΣ 341 ...	18 1	68 34	86·3	0·32	2	6·4	7·7	·624	B.
Σ 2283... ...	18 4	83 52	80·4	1·08	2	7·2	7·7	·575	W.B.
Σ 2281... ...	18 5	86 2	228·6	0·36	2	5·7	7·2	·575	W.B.
Σ 2289... ...	18 6	73 32	228·6	1·20	3	6·5	7·0	·511	W.B.
			223·0	1·31	1	...		·578	H.F.
Σ 2294... ...	18 9	89 5	106·5	0·25	1	7·4	7·7	·542	B.
			76·6	0·31	1	...		·654	W.B.
Hussey 197...	18 15	79 46	32·7	0·37	1	8·2	9·3	·652	W.B.
β 641	18 17	68 32	344·7	0·78	4	7·5	9·0	·651	L.
*	18 18	69 30	338·5	2·30	1	7·5	9·0	·665	L.
*	18 18	69 30	195·1	2·60	1	8·0	9·0	·665	L.
Σ 2315... ...	18 21	62 39	198·5	0·34	1	7·0	8·0	·665	L.
*	18 20	62 40	319·4	3·50	1	9·5	10·5	·665	L.
Σ 2318... ...	18 21	64 4	241·5	11·93	1	8·0	10·2	·731	L.
β 1203... ...	18 21	89 15	72·0	0·15	1	7·5	7·7	·542	B.
OΣ 354 ...	18 27	83 18	174·0	1·11	1	7·2	8·0	·685	H.F.
OΣ 357 ...	18 31	78 21	238·2	0·39	1	8·2	8·2	·590	W.B.

r's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1902.	Obs.
	h m	° ′	°	″					
8 ...	18 31	73 6	13·3	1·77	2	6·8	7·2	·523	W.B.
87 ...	18 34	73 34	100·9	0·33	1	7·8	8·1	·652	W.B.
5... ...	18 34	61 23	60·3	1·14	2	8·2	8·6	·584	W.B.
... ...	18 34	61 18	253·9	1·27	2	9·0	10·0	·584	W.B.
17 ...	18 37	58 27	117·7	0·33	1	8·3	8·5	·611	L.
'... ...	18 37	59 48	78·2	0·22	1	7·2	7·6	·611	L.
)... ...	18 39	87 29	91·4	1·06	1	8	8	·674	B.
;... ...	18 41	84 36	114·0	1·77	4	6·2	6·6	·666	H.F.
1... ...	18 45	79 25	205·9	1·23	1	8·0	8·4	·652	W.B.
			207·4	1·23	1	...		·679	H.F.
... ...	18 46	78 36	230·2	1·25	1	7·7	9·3	·611	L.
r 199...	18 47	78 19	6·2	0·41	1	8·7	9·1	·611	L.
1... ...	18 53	64 2	96·9	0·95	3	7·6	7·7	·634	W.B.
...	18 53	57 16	217·3	1·00	1	6·0	9·2	·633	L.
...	18 54	76 31	267·0	16·50	2	5·7	9·2	·681	H.F.
...	18 58	70 58	63·0	0·91	2	7·8	8·0	·611	W.B.
...	19 3	67 59	76·8	3·39	3	7·2	8·3	·695	H.F.
			76·1	3·25	2	...		·751	W.B.
...	19 4	63 4	127·5	0·27	1	8	8	·687	L.
...	19 7	87 33	2·3	0·31	1	7·7	8·5	·542	B.
...	19 11	70 9	326·9	1·55	2	8·5	9·7	·662	W.B.
			331·5	1·29	1	...		·679	H.F.
3 ...	19 12	74 1	216·8	0·98	3	7·3	8·5	·622	W.B.
1 ...	19 12	62 42	151·9	0·82	3	6·8	7·0	·651	W.B.
			153·5	0·94	1	...		·679	H.F.
...	19 14	83 51	36·8	0·68	3	8·3	8·3	·641	B.
...	19 18	67 42	84·8	0·66	2	7·5	8·5	·693	W.B
...	19 19	37 50	339·7	0·30	1	6·3	6·3	·728	B.
5 ...	19 23	62 52	313·2	0·43	3	8·0	8·0	·611	W.B
			313·3	0·45	1	...		·665	L.
5 ...	19 30	72 7	146·6	0·57	3	7·2	8·4	·665	W.B.
...	19 32	81 56	240·1	16·01	1	7·8	9·5	·742	L.
11 ...	19 45	71 7	156·5	0·16	2	4·5	6·0	·624	B.
...	19 46	86 10	101·3	3·72	2	6·5	9·2	·682	H.F.
...	19 47	79 55	308·6	13·42	1	7·1	10·0	·742	L.
0 ...	19 48	67 48	273·5	0·57	1	8·0	8·1	·652	W.B.
			268·7	0·68	1	...		783	B.
...	19 50	83 50	12 3	12·13	1	3·4	11·3	·742	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1902.	Obs.
	h m	° ′	°	″				
Σ 2600 ...	19 51	67 46	55·3	2·88	3	8·3 9·7	·710	W.B.
β 425 ...	19 53	69 59	241·1	1·52	3	8·4 8·5	·665	W.B.
A.C. 16 ...	19 54	63 2	59·0	0·34	3	7·8 8·2	·661	W.B.
β 439 ...	19 57	60 27	237·3	3·23	1	7·9 12·7	·671	L.
β 1258 ...	19 57	60 22	156·8	1·45	1	8·0 10·8	·671	L.
*	19 57	60 22	303·7	2·77	1	8·5 9·0	·671	L.
OΣ 395 ...	19 58	65 21	96·4	0·57	1	5·8 6·2	·570	W.B.
			99·6	0·61	1	...	·671	L.
			103·6	0·66	2	...	·701	B.
Σ 2616 ...	19 58	75 42	265·7	3·53	2	6·8 9·7	·762	W.B.
Σ 2620 ...	19 59	78 30	291·2	1·72	1	8·2 9·3	·789	W.B.
Σ 2624 ...	20 0	54 15	174·7	1·93	1	7·2 7·8	·734	W.B
Σ 2695 ...	20 28	64 32	81·0	1·09	2	6·2 8·0	·562	L.
			74·6	1·05	1	...	·734	W.B.
β 670 ...	20 28	76 24	34·1	0·59	3	8·5 8·9	·596	L.
*	20 28	76 23	135·3	0·44	2	9·0 9·5	·561	L.
β 151 ...	20 33	75 45	19·8	0·40	1	4 6	·677	L.
			20·1	0·40	4	...	·742	B.
			19·1	0·31	1	...	·734	W.B.
Ho. 137 ...	20 37	60 33	288·5	1·03	1	7·0 10·0	·734	W.B.
*	20 37	60 33	338·6	6·86	1	8·0 10·5	·734	W.B.
Σ 2737 A.B.	20 54	86 5	278·5	0·76	2	5·7 6·2	·745	B.
A.C.			74·0	10·66	1	5·7 7·4	·722	H.F.
OΣ 424 ...	20 55	74 49	318·1	0·48	1	7·5 8·7	·677	L.
OΣ 535 ...	21 10	80 24	See end of list.					
Σ 2799 ...	21 24	79 21	297·3	1·30	2	6·6 6·6	·800	H.F.
			298·7	1·57	2	...	·838	W.B.
Σ 2804 ...	21 28	69 44	334·1	2·62	2	7·3 8·0	·800	H.F.
			332·2	2·77	2	...	·811	W.B.
β 1212 ...	21 34	90 37	269·3	0·51	1	6·5 6·9	·706	B.
Hough 166 ...	21 40	62 37	90·2	0·32	3	7·5 7·5	·825	L.
Σ 2822 ...	21 40	61 42	123·4	2·34	2	4·0 5·0	·783	L.
			123·8	1·98	2	...	·800	H.F.
β 989 ...	21 40	64 49	See end of list.					
Ho. 171 ...	21 48	62 40	350·5	0·73	3	8·0 8·2	·760	L.
β 75	21 51	79 35	41·3	1·12	1	8·1 8·3	·887	W.B.
Hough 179 ...	22 8	60 17	260·2	0·42	1	8 9	·862	L.
			269·3	0·33	1	...	·887	W.B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1902.	Obs.
Σ 2881 ...	22 10	60 55	99·4	1·39	2	7·7	8·2	·827	W.B.
Hough 180 ...	22 12	46 36	225·7	0·50	1	7·2	7·2	·715	L.
β 1216 ...	22 16	60 59	306·3	0·44	2	8·4	8·7	·876	W.B.
β 172 ...	22 19	95 21	0·8	0·55	1	5·6	6·0	·706	B.
Σ 2900 ...	22 19	67 39	177·8	1·37	2	6·0	9·2	·838	W.B.
β 291 ...	22 23	85 39	167·3	0·40	2	8·4	8·7	·789	L.
β 701 ...	22 23	78 12	261·4	1·03	1	7·5	10·2	·715	L.
β 1218 ...	22 23	60 49	56·2	1·45	1	8·6	8·8	·887	W.B.
β 1291 ...	22 25	32 48	122·0	3·49	1	9·1	10·5	·715	L.
Σ 2912 ...	22 25	86 5	290·1	0·36	1	5·8	7·2	·789	L.
β 705* ...	22 29	49 42	—	—	1	7·0	12·5	·715	L.
Hough 296 ...	22 36	75 59	82·7	0·29	2	5·5	5·5	·728	B.
			88·8	0·22	3	...		·828	L.
Σ 2934 ...	22 37	69 5	136·3	0·84	2	8·2	9·2	·838	W.B.
β 710 ...	22 38	60 48	235·9	0·45	2	8·5	8·6	·786	L.
β 1144 ...	22 39	60 18	95·1	0·36	1	10·1	10·1	·709	L.
β 711 ...	22 40	79 20	32·5	0·99	1	8·5	10·0	·709	L.
β 1146 ...	22 44	53 26	295·6	—	1	7·2	8·2	·917	L.
02 Σ 536 ...	22 53	81 10	331·5	0·25	1	7·0	7·5	·805	B.
			344·5	0·31	2	...		·873	L.
Σ 2958 ...	22 52	78 41	11·3	4·66	1	7·2	9·5	·961	L.
02 Σ 483 ...	22 54	78 48	224·7	1·06	3	6·2	7·7	·902	L.
β 1147 ...	22 58	47 47	325·2	—	1	5·5	8·7	·917	L.
β 1025 A.B....	23 2	77 52	277·5	0·80	2	8·0	10·3	·923	L.
A.C....			86·4	22·58	1	8·0	12·0	·884	L.
Σ 2995 ...	23 11	92 8	211·5	4·85	1	7·7	8·0	·922	L.
β 79	23 12	92 4	87·0	0·97	1	8·0	8·6	·922	L.
β 80 A.B. ...	23 14	85 8	9·3	0·45	1	8·2	9·1	·917	L.
			39·3	0·29	1	...		·750	B.
β 80 A.C. ...			4·7	103·95	1	8·2	10·5	·917	L.
C.E. ...			135·4	21·36	1	8·2	14·0	·917	L.
β 719 ...	23 19	76 4	5·2	1·27	1	7·2	11·0	·906	L.
β 1266 A.B....	23 25	59 44	11·1	0·20	4	7·4	7·4	·833	L.
			21·2	0·15	1	...		·783	B.
Σ 3018 A.C....			203·8	19·03	1	7·4	9·0	·799	L.
β 720 ...	23 29	59 14	348·2	0·39	3	6·0	6·5	·809	L.
			344·3	0·37	1	...		·783	B.

* See end of measures.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1902.	Obs.
	h m	° ′	°	″					
β 858 A.B. ...	23 36	58 0	262·6	0·65	2	7·7	8·2	·858	L.
β 389 A.C. ...			52·9	22·83	2	7·7	10·8	·858	L.
Σ 3050 ...	23 54	56 50	218·4	2·18	1	6·0	6·0	·794	H.F.
β 281 ...	23 57	88 25	197·6	1·39	1	7·5	9·2	·922	L.
β 733 ...	23 57	63 26	249·7	0·75	1	6·0	11·0	·906	L.
Σ 3056 ...	23 59	56 17	149·0	0·45	2	7·4	7·4	·767	B.

Capella.

Observer ... ... Mr. Lewis.

Date. 1902.	Hour Angle.	Day from Beginning of the Year.	Position Angle.	Remarks.
d h			°	
Jan. 24	4½ 4½E.	23·1	(272)	Power 670. The nucleus is very distinct and elongated along the line in which the instrument is vibrating. The star has just the same appearance as when first seen in 1900 April. When clouds passed, the rings and glare became elliptical along this line, so that I should put the elongation down to the clock.
	4½ 4½E.		(268)	
	4¾ 4¾E.		(254)	
Mar. 3 11	3½W	63·5	26 36	Power 670 and 1120. Splendid definition. Large number of rings; star certainly elongated at 206° or 26°. The diameter of the star was measured first in the direction of apparent elongation and then at right angles to this direction. The difference gave 0″·12, corresponding to a separation of the centres of two stars, considered equal, of 0″·060.
Apr. 8 8¼	4 W	97·3	...	Powers 670 and 1120 Star well defined. Large number of rings. Quite round.
10 8½	4 W	99·3	...	Powers 670 and 1120. Definition fair, image steady, and a large number of rings. No sign of elongation.
Dec. 4 9	3 E.	336·3	...	Definition bad. No nucleus.

Observer ... ... Mr. Bryant.

d h			° ′	
Jan. 24 4	5 E.	23·2	112 19	Power 670. Windy. Definition good at times. Apparently second quadrant.

Date. 1902.		Hour Angle.	Day from Beginning of the Year.	Position Angle.	Remarks.
	d h			° ′	
ı.	30 4	4¼E.	29·2	91 34	Power 670. Windy. Definition fair at intervals. Two blue shades and one green one.
ıb.	12 5	2¾E	42·2	49 20	Power 670. Two blue shades. Star very small. Definition good (more than six complete diffraction rings). Elongation very slight. Apparently in first quadrant.
lar.	12 8½	2½W.	70·4	338 43	Power 670. Two blue shades. Star very bright, many rings visible. Disc at times well defined and small. Elongation estimated between 0″·05 and 0″·07. Bright field.
ıpr.	9 7½	3¼W.	98·3	239 32	Power 670. Definition poor, some measures through cloud, others with two blue shades.
	17 7½	4 W.	106·3	211 21	Power 670. Bright sky. Two blue shades. Star very small and almost round.

Observer ... ... Mr. Bowyer.

	d h			° ′	
Jan.	13 7	2¾E.	12·3	...	Power 670. May possibly be elongated at 240°, but very doubtful. Definition fair.
Mar.	17 10½	5 W.	75·4	298 38	Power 670. Definition good, several rings visible. Blue shade used. Elongation apparently in second quadrant

Schiaparelli (Σ 1273 A.B., ε *Hydræ*).

Observer ... ... Mr. Lewis.

Date.	Position Angle.	Dist.	
1902·167	357°·5	<″·2	Definition rapidly getting bad, and sky covered with thin cloud; but it is believed that the angle is fairly good. Power "670."
·216	36·7	< 1	Definition fair. Power 670.
·266	25·9	·18	Definition good. Estimated distance not greater than 0″·2.
·320	28·7	<·1	The dot of light measured was only visible occasionally, but I think it was the companion: it appeared slightly reddish, and right on the limb of the large star. The distance would not exceed 0″·1. Power 670.

Observer ... ... Mr. Bryant.

Date.	Position Angle.	Dist.	
	°	″	
1902·301	280·0	0·10	Power 670. Bright sky. Elongation slight and very doubtful.

δ *Equulei* (0Σ 535).

Observer ... ... Mr. Lewis.

1902·611	...	...	κ Pegasi (0″·13) measured fairly easily, about the same time, and judging from this δ *Equulei* must be nearly, if not quite, round.
·709	...	...	If elongated the distance cannot be anything like 0″·1. When seen at best definition it appeared round.
·715	...	...	Cannot detect any elongation. Definition not so good as on last occasion (709).
·794	21·2	0·20	Elongation undoubted and estimated between 0″·1 and 0″·2.
·867	28·7	0·18	Elongation was marked and quite 0″·15. I suspect the companion in the first quadrant to be paler than the other.
·917	29·0	0·22	Definition good.

Observer ... ... Mr. Bryant.

1902·476	19·4	0·13	Bright field. Elongation very slight.
·542	27·2	0·18	Bright field. Not separated.
·706	28·8	0·21	Bright field. Elongated.
·783	28·7	0·22	Elongation slight.
·805	28·6	0·21	Elongated.

κ *Pegasi.*

Observer ... ... Mr. Lewis.

1902·611	180·4	0·13	Definition fair.
·709	167·3	0·1	Distance estimated.
·715	180·5	0·17	Difficult; measure of distance too large.
·805	...	...	Cannot measure, although δ *Equulei* was measured by Mr. Bryant.
·857	...	...	Cannot measure.
·862	147·9	0·14	More difficult than δ *Equulei*.
·917	145·4	0·15	„ „

Observer ... ... Mr. Bryant.

Date.	Position Angle.	Dist.	
	°	″	
902·542	180·4	0·11	Bright field.
·706	153·8	0·16	Observation not good.
·783	157·8	0·12	Bright field.

β 705.

This star was discovered by Mr. Burnham with the 18½-inch Dearborn refractor; the magnitudes are 7·0 and 12·5. The observations:—

1878·53	158·0	1·5 ±	Burnham.
1885·64	...	...	Hermann Struve. Single.
1898·	...	...	Burnham. Single.
1902·72	74·0	0·72	Lewis. No companion could be seen in position given for 1878; but a minute companion was suspected in the position now given.

Note on the Double Star 31 Leonis. By S. W. Burnham.

The Anderson companion to 31 *Leonis* has not been measured until recently in the last twenty-five years, and as the bright star has a considerable proper motion there would be a very decided change in the position of the $13^{m}\cdot5$ attendant if it was only an optical pair. It was therefore placed on my working list for measurement. The following are all the observations of this pair:

	°	″	
1878·24	44·2	7·63	2*n* β
1878·30	43·3	7·94	5*n* Hl
1903·19	41·9	7·64	3*n* β

It is evident that there has been no sensible change, and that the faint star has the same proper motion as the other. This is given by Auwers as 0″·127 in the direction of 252°·6. If the companion was fixed in space the distance in this interval would have increased nearly two and one-half seconds, so there can be no doubt as to this being a physical system.

In making these measures I noticed that one of the DM

stars given as closely following 31 *Leonis* is now missing. The places from that catalogue for 1855 are :

	h	m	s	°	′
31 *Leonis*	10	0	10·3	+10	43·4
(10°) 2117 (9·5)	10	3	17·2	10	37·3
2118 (9·5)	10	3	25·2	10	38·3
2119 (9·1)	10	3	34·3	10	43·3

Neither of the three small stars is given in the A.G. Catalogue, but the last is found in the Toulouse Catalogue, and also in Bonn No. 4. Only two of these stars are to be found now. One is 2119, and the other is probably 2118, although the difference in declination does not agree with the present position of the stars. The relation of 2119 and the other star is :

1903·22 P = 185°·7 D = 73″·70

One of these stars might have some proper motion, but it is more probable that the missing star and the apparent change in position are to be explained by errors in the DM.

The small nebula, *Dreyer* 3130, is in a low-power field with 31 *Leonis*. My direct measures from that star give :

1903·22 P = 106°·9 D = 296″·6

This gives substantially the same place as that in Dreyer's General Catalogue.

The Yerkes Observatory :
April 30.

New Companion to Σ 1594. By S. W. Burnham.

The double star Σ 1594 was placed on the working list in order to make another set of measures for a determination of the proper motion shown in the prior observations. In observing the Σ companion with the 40-inch, a much nearer component was detected which has not been seen heretofore. This star was estimated $13^{m}\cdot3$, and the mean result in position is :

1903·21 P = 318°·2 D = 1″·57 3*n*

The proper motion of A, assuming C to be fixed, I have ced from the following measures :

1831·93	165°·0	16″·95	2*n* Σ
1867·39	162·6	15·42	3*n* Δ
1879·26	160·4	15·22	1*n* β
1886·40	159·8	15·17	4*n* Hl
1903·19	158·1	14·46	4*n* β

These positions give for the most probable movement of the cipal star 0″·043 in the direction of 200°·5. Struve's nitudes of A and C are 8·7 and 10·5. The brighter is DM) 2267, where it is called $9^{m}\cdot2$, and the place for 1880 from A.G. Catalogue is :

R.A. $11^{h}\ 57^{m}\ 20^{s}$
Decl. 42° 4′ 25″

There is a more distant fourth star of about the same magni- e as the close component, which is not mentioned by Σ. The y measures are :

1886·40	77°·3	25″·15	2*n* Hl
1903·20	76·0	25·02	3*n* β

Like C, it is probably only an optical companion, but the asures do not cover a sufficient time to make this apparent.

The Yerkes Observatory :
April 30.

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MONTHLY NOTICES

OF THE

'AL ASTRONOMICAL SOCIETY.

II. JUNE 12, 1903. No. 8

ır H. H. TURNER, M.A., D.Sc., PRESIDENT, in the
.r.

Pratt, B.A., B.Sc., 14 Endwell Road, Brockley, S.E.,
d for and duly elected a Fellow of the Society.

llowing candidates were proposed for election as
he Society, the names of the proposers from personal
being appended :—

ıder Philip Dumas, R.N., F.R.G.S., Instructor in
tricity and Submarine Mining, &c., Royal Naval
acks, Chatham (proposed by E. J. Spitta) ;
Eichbaum, Granville Hill, Eastbourne, Sussex (pro-
d by G. F. Chambers) ;
Flowers, Map Officer, Ginsberg Chambers, Johannes-
, Transvaal, South Africa (proposed by R. T. A.
s) ; and
leorge Macrory, M.D., B.A., &c., Clifton House,
ge Road, Battersea, S.W. (proposed by A. Fowler).

-five presents were announced as having been received
st meeting, including, amongst others :

aphic map of the heavens ; fifty-five plates taken at
ɔmical Observatory of Harvard College, presented by
. C. Pickering ; a series of photographs (transparencies)
solar eclipses of 1898, 1900, and 1901, taken by the Lick
Expeditions, presented by the Lick Observatory ;
arency spectro-heliograph of the Sun, taken at the
ervatory, presented by Professor G. E. Hale.

Examination of Mr. Whittaker's "Undulatory Explanation of Gravity" from the Physical Standpoint. By G. Johnstone Stoney, M.A., Hon. Sc.D., F.R.S.

In the part of the *Monthly Notices* issued last September, at p. 619 of vol. lxii., there is a suggestive paper by Mr. Edmund T. Whittaker dealing with three topics.

1. In the first section of his paper he gives a striking and most useful general solution of Laplace's Differential Equation for the potential of gravity, viz. of the equation

$$\nabla^2 V = 0, \text{ or a constant.} \quad \ldots \quad \ldots \quad (1)$$

2. In the second section by a similar method of treatment he obtains a singularly elegant proof of the recently discovered theorem that the wave-motion represented by the equation

$$\nabla^2 V = \frac{1}{k^2} \frac{\partial^2 V}{\partial t^2} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

(in other words, wave-motion which is propagated with constant speed k in all directions through an isotropic medium) can be analysed into components, each of which is an undulation of flat wavelets. This is the principal case of a more general theorem which effects the resolution in crystalline as well as isotropic media; and this proof in the case of isotropic media,* for which we are indebted to Mr. Whittaker, has deduced the resolution from the fundamental differential equation of such motion, and is therefore a most welcome addition to the previously known proofs of the theorem.

3. In the last section of his paper Mr. Whittaker develops "An undulatory explanation of gravity" which aims at "analysing the field of force [? acceleration †] due to a gravitating body by a 'Spectrum Analysis,' as it were, into an infinite number of constituent fields . . . of an undulatory character." This rather

* It seems likely that Mr. Whittaker's remarkable handling of equations (1) and (2) could present the general solution of equation (2) as an integral of elements each of which is an undulation of flat wavelets, in the case where k is a function of the polar coordinates θ and ϕ, as well as in the case dealt with by Mr. Whittaker where k is a constant in reference to θ, ϕ, and r. It would be of much interest to ascertain whether this is so, but the present writer has not gone sufficiently into this question. If so, Mr. Whittaker's analysis will extend to crystalline as well as isotropic media, just as the method of proof by the Principle of Reversal does (see *British Association Report* for 1901, p. 570). It may be desirable to add that the proof by the method of Reversal supplies further information which is of use in making experiments, inasmuch as it exhibits the relation in which the resolution into flat wavelets stands to resolutions into wavelets of other forms. It seems probable that this information could not be obtained without much difficulty by the analytical method.

† See "How the Misuse of the Word *Force* may be avoided," *British Association Report* for 1894, p. 586.

artling announcement seems to require further discussion than at given to it by its author, in order that we may understand hat the proposed resolution means *physically* and what it does ɔt mean. The physical meaning of his equations is not referred › in Mr. Whittaker's paper, and an inquiry into it is therefore ndertaken here, since without some knowledge about it we are ɔt in a position to form a judgment as to the true value of the ɔolution.

4. In the department of physics to which Mr. Whittaker's ıvestigation belongs a differential equation has first to be so contructed as to express the fact that physical causes, acting under efinite laws, are in operation; and having obtained this lifferential equation by a study of the laws under which the hysical causes act in the problem of nature which is under nvestigation, then the innumerable particular solutions of that lifferential equation will represent the several events in nature vhich those physical causes are competent to produce.

5. Thus, in acoustics, the differential equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{k^2}\frac{\partial^2 y}{\partial t^2}$$

epresents the physical causes that govern the transverse vibraions of a uniform flexible and elastic string when stretched and et vibrating, so long as the range of vibration is small; and the undamental note emitted by this string and all its harmonics resent themselves as motions represented by particular soluions of this equation. In this and all analogous cases the um of any of these particular solutions will also be a solution of he differential equation; the physical meaning of which is that ny group of the harmonics, or of the harmonics and fundamental one, produce a complex resultant tone of which the members of hat group are true physical components.

A similar state of things prevails when we investigate athematically that spectrum analysis of light to which Mr. Vhittaker likens his analysis of gravity. Each of the luminous ndulations is a particular solution of the differential equation hich is to be employed when dealing with light; and *any* group f these particular solutions when added together represents a sultant luminous effect of which the members of that group are nuine physical components.

The same is also true of that other resolution of light into its t wavelet components which is dealt with by Mr. Whittaker the second part of his paper. Here, again, the resultant is e sum of the components, and the components and resultant e all of them solutions of the fundamental differential equation: other words they are, whether taken separately or as coexisting any group, effects which the physical causes represented by e differential equation are competent to produce.

The same holds true of fields of potential due to gravitation.

Each attracting centre produces its own field of potential, and the coexistence of any number and any disposition of attracting centres produces a resultant field which is represented mathematically as the sum of the component fields.

6. All these are cases in which, by applying an unrestricted treatment to the differential equation, we obtain true physical resolutions; but the resolution of gravity suggested by Mr. Whittaker is of a different kind. In the first place it does not result from an unrestricted treatment of the differential equation, since it is only by picking out one particular and very special solution of the equation which Mr. Whittaker suggests shall be substituted for Laplace's equation, that we can arrive at his resolution; and it only remains to inquire what is the physical meaning of the process by which this artificial resolution is obtained.

7. To convert Mr. Whittaker's analysis into a form which will exhibit its physical meaning, it will suffice to differentiate his equations by r, and thus transform them from equations that refer to potential into equations that refer to accelerations. The definite case with which Mr. Whittaker deals is that of the field of potential called into existence by an attracting centre situated at the origin of coordinates. In this case his undulatory components assume the form

$$dV = \frac{2d\mu}{\pi\mu} \cdot \frac{\sin \mu(kt-r)}{r} \quad \ldots \quad \ldots \quad (3)$$

where μ is the wave-frequency and k the speed of propagation of the undulation. Differentiating this equation by r we obtain the following expression for the corresponding component of the attracting acceleration :—

$$dR = -\frac{2d\mu}{\pi}\left(\frac{\sin \mu(kt-r)}{\mu} \cdot \frac{1}{r^2} + \cos \mu(kt-r) \cdot \frac{1}{r}\right) \ldots \quad (4)$$

This shows that this component of the field of acceleration consists of two attractions at each distance r from the origin, one an acceleration varying inversely as the distance, the other an acceleration varying inversely as the square of the distance, and both multiplied by coefficients which make their intensity at each point of space fluctuate periodically with the frequency μ.

8. Accordingly the general outcome is that we are to imagine two infinite series of accelerations the terms of which correspond to all possible values of μ, one series consisting of accelerations varying inversely as the distance, the other of accelerations varying inversely as the square of the distance, and all these accelerations flickering in intensity at each point of space in definite ways. Then what the physicist learns from Mr. Whittaker's analysis is that *there is one definite set of coefficients* which if prefixed to these innumerable flickering accelerations will enable them to furnish an unvarying resultant at each point of space.

ıs is an effect of a kind which it is antecedently probable could suitable manipulation be brought about; but unfortunately ults obtained by such manipulation, though pleasing from ir ingenuity, do not hold out any prospect of being of service the student of dynamical astronomy.

9. Viewed from the mathematical standpoint, Mr. Whittaker's restigation amounts to this, that when we integrate equation we find in it an instance of a state of things occasionally t with—viz. that where a variable, such as r in equation (3), esents itself both under and outside a sign of integration, then is variable as it exists outside the sign of integration will alone rvive when the integration is taken between definite limits. ıis, for example, will happen whenever, as in the present stance, viz., in—

$$V = \frac{2}{\pi r}\int \frac{\sin \mu(kt-r)}{\mu} d\mu \quad \ldots \quad \ldots \quad \ldots \quad (3a)$$

$$V = \frac{2}{\pi r}\int \frac{\sin \mu(kt-r)}{\mu(kt-r)} d[\mu(kt-r)] \quad \ldots \quad \ldots \quad (3b)$$

ıe variable in question only appears under the sign of integration in a form in which it can be presented as part of a efficient to the variable by which we are integrating, and when ıe limits of integration are then made cipher and infinity. In r. Whittaker's integral the transversal (or square root of the tensity) of each element of the series represented by the tegral is assumed to be proportional to $1/\mu$, the wave-length, and hen this very special set of values are assigned to the coficients of the terms of the series represented by the integral, en r under the sign of integration, which is essential to the ysical interpretation, is excluded from the resultant while pearing in the components. This produces the semblance of a solution notwithstanding that in the components on the one nd, and in the resultant on the other, we are dealing mathetically with differential equations—equations (1) and (2)—the neral solutions of which are not physically connected. What r. Whittaker has shown is that one particular solution of equation) can be obtained by a definite integration so contrived as to literate *in that particular solution* the physical incompatibility ıich in general prevails between equations (1) and (2). This ıuld, possibly, not be an altogether illegitimate process if the ysical events which would justify it were such as we might ume to prevail in actual nature. The physical assumption be made is that the attraction of each particle of ponderable tter can be of that extraordinary kind described above in ragraphs (7) and (8). But, unfortunately, the improbability this assumption is so overwhelming that no *physicist* can feel nself justified in seriously arguing from the supposition that it presents the state of things which exists in nature, however

much he may be impressed by the mathematical ingenuity of t investigation.

Postscript.

A discussion followed the reading of this paper in which was pointed out that there exist motions in the solar syste which cannot be wholly accounted for by gravitation acting i accordance with Laplace's Differential Equation; and it wa suggested that this indicates that Laplace's equation require modification, at least for bodies in relative motion. Now Laplace's equation has to be modified it appears certain fro the physical interpretation of Mr. Whittaker's equations tha the modification cannot be that substitution of equation (2) fo Laplace's equation which is suggested by Mr. Whittaker; an that what we learn from the investigation is that we may limi the inquiry by dismissing this alternative when searching fo the modification.

But has it been quite ascertained that the observed motion may not be due to causes already known? We are acquainte with at least three causes acting within the solar system whic *must* produce deviations from Newtonian motions. The chief o these is the meteoric streams and sporadic meteorites whic dash about in vast swarms within the space through which th visible bodies of the solar system have to travel. Another suc cause is the escape of gases from atmospheres (see *Astrophysica Journal* for June 1900, Appendix, p. 369). This escape we hav reason to believe takes place chiefly from the side of a plane turned towards the Sun, and therefore produces on the planet a one-sided effect; and a third cause which is known to exist i electric. Modern astronomers are able to compute perturbation with such refinement that it does not seem impossible that th first of the above *veræ causæ* may produce effects of sufficien amount to be detected.

It is noteworthy that at least the first two of these *vera causæ* would operate with more intensity upon *Mercury* than upon our Earth: witness much other evidence, corroborated by the existence of such phenomena as the Solar Corona and the Zodiacal Light.

Note on the Present Condition of the Lunar Theory.

By E. Nevill.

1. The recent discussion at the March Meeting of the Roya Astronomical Society on Professor Newcomb's note, entitle "On the desirableness of a reinvestigation of the problem growing out of the Mean Motion of the Moon," suggests m furnishing some information with respect to the researches c

ıe motion of the Moon which have been carried out at the atal Observatory.

2. First with respect to the comparison of the observed and ıbular places of the Moon. The whole mass of observations ɔntained in Professor Newcomb's "Reduction and Discussion f Observations of the Moon before 1750" (Washington, 1878); ı Sir G. Airy's "Greenwich Lunar Reductions for 1750 to 1830," ıd its extension "The Greenwich Lunar Reductions for 1831 to 351"; and the complete series of Greenwich Observations of ıe Moon made with the Transit Circle between 1851 and 1899, ıve all been reduced on a uniform system of star places and ements of reduction, to a homogeneous series of comparison etween observation and Hansen's "Tables de la lune."

There are thus obtained a homogeneous complete series of ɔmparison between observations and tables extending over the eriod 1630 to 1900. This may be called "Data A."

3. The preceding comparison between the observed and ıbular places of the Moon is insufficient as it stands to furnish ıy explanation of the origin of the outstanding discrepancies hose existence it reveals. For this purpose what is required to so combine the results of the comparison between observation ıd tables, that they will yield separately for each year—

(1) The coefficient expressing the mean error depending on the Moon's Mean Longitude.

(2) The coefficient expressing the mean errors depending on the sine and cosine of the Moon's *Mean Anomaly*.

(3) The coefficients expressing the mean errors depending on the sine and cosine of the *Variation*.

(4) The coefficients expressing the mean errors depending on the sine and cosine of the *Annual Equation*.

(5) The coefficients expressing the mean errors depending on the sine and cosine of the *Parallactic Inequality*.

(6) The coefficients expressing the mean errors depending on the sine and cosine of the *Evection*.

(7) The coefficients expressing the mean error of the Moon's Parallax and its variation.

(8) The coefficients expressing the mean error varying directly as the Moon's Latitude.

(9) The coefficients expressing the mean errors varying as the sine and cosine of the Argument of Latitude.

The available observations prior to 1750 are too few to enable hese to be systematically calculated for each year, but for the ne hundred and fifty years from 1750 to 1899, from the pre-ɛding comparison between Hansen's tabular place of the Moon nd that as observed at Greenwich, there have been computed for ıch year the value of the preceding eighteen coefficients. In ddition the more accurate modern places of the Moon obtained y means of the Greenwich Transit Circle since 1851, have been

utilised for computing the separate yearly values of a number of other coefficients depending on other auxiliary arguments.

The long series of yearly values of these different coefficients furnishes full data for the investigation from the observations of the origin of the outstanding imperfections of Hansen's Tables. They may be called "Data B."

4. These outstanding imperfections in Hansen's Tables may be divided into the following classes :—

(1) Errors in the theoretical values for the coefficients of the perturbations due to the direct action of the Sun employed in the theory embodied in Hansen's "Tables de la lune."

(2) Consequential errors due to Hansen having adopted erroneous values for the different constants depending on observation which are involved in his theory.

(3) Errors in the values assigned by Hansen to the perturbations due to the disturbing action of the planets, the figure of the Earth and similar causes, and omission of terms representing perturbations of sensible magnitude whose existence he had overlooked.

Considering the first of these classes, it may be taken that the values assigned by Hansen in the "Darlegung" to the ordinary lunar solar perturbations correspond very closely to the true theoretical values, if Hansen's values for the constants be adopted. There are few cases where the error in the coefficients exceeds some hundredth of a second of arc. Generally, they agree with the values found by Delaunay, when both are reduced to the same basis. In all cases where there exists any material discrepancy between the theoretical values of Hansen and Delaunay, the correct value of the coefficient has been recomputed, carrying the calculation when necessary to the eleventh power of m. The existing discrepancies arise mainly from Delaunay not having carried his computations far enough to obtain the complete value of the coefficient, but in some cases they are due to Delaunay having overlooked combinations of terms contributing to the complete value. In a very few cases Hansen's value seems incomplete, probably from the accidental omission of terms of high order. It is true that the values of these coefficients embodied in Hansen's Tables are not identical with the final values given in the "Darlegung," but the differences are comparatively unimportant, and no revision of theory will sensibly alter the great mass of theoretical values embodied in Hansen's Tables.

With respect to the second of these classes, the values assigned by Hansen to the constants which have to be derived from observation, nearly all require material amendment. This is especially the case with respect to the secular motion of the *Mean Longitude*, of the *Longitude of Perigee*, and of the *Longitude of Node*, as well as with the value assigned to the *Secular Accelera-*

tion, and the ratio of the parallaxes of the Sun and Moon. But in addition corrections are required to the values employed by Hansen for the constants of *Eccentricity* of *Inclination* and of *Parallax*.

The corrections to Hansen's tabular values of these constants have been derived from the complete series of values termed "Data B," and Hansen's Tables amended by supplying the requisite auxiliary tables necessary to take them into account. For the sake of completeness it has been necessary to do this on two separate systems.

1st. By supposing that Hansen's Tables are complete as they stand, and that after rectifying an admitted error, they merely require the removal of the admittedly incorrect empirical term depending on the argument (8 V − 13 E).

2nd. By admitting that Hansen's Tables are not complete, but after the removal of the empirical term, require supplementing by the addition of certain smaller terms due to the action of the planets, such as the *Jovian Evection*, of whose existence and approximate value there can be no question.

Yet the difference between the two resulting systems of corrections is far less than might have been imagined.

It is with the third class of imperfections in Hansen's Tables that the main difficulty arises. The values which Hansen determined from theory for the coefficients of the perturbations of this character, all need some correction, for in no case has he carried his computations far enough to obtain the complete value. Generally speaking, the difference is not large enough to be of importance, but in the case of the terms depending on the longitude of the Moon's Node, and the perturbation of *Venus*, there is a considerable difference between Hansen's value and the true values of the terms.

But the crucial point is: How many terms of this class having sensible magnitude are absent from Hansen's Tables? About half a dozen there can be no question, mainly the planetary evectional terms; but how many beyond these, and of what magnitude and what period? Therein lies the difficulty. Opinion varies.

5. The long series of values for each year of the coefficients of the principal inequalities in the motion of the Moon, which constitutes "Data B," can be made to show what are the inequalities which are not included in Hansen's Tables, and yet are necessary to reconcile the observed and tabular places of the Moon.

They have been employed for this purpose, and by the suitable discussion of the variations in the yearly values of the twenty different coefficients, there have been deduced the probable periods of the different outstanding terms, and the approximate values of their coefficients.

Some of these outstanding terms are found to correspond closely in both period and coefficient with those known to exist and to be absent from Hansen's Tables, and the fact that the values so determined correspond so closely with the values furnished by theory furnishes the strongest evidence of the reality of the existence of the other similar terms whose values are not so readily determined from theory.

6. The full details of the results of the reduction and discussion of this great mass of observations as compared with Hansen's Tables, has been lying for some time at the Natal Observatory awaiting publication. For it was decided by the Natal Government that as the work represented a considerable part of the scientific work done at the Colonial Observatory, it must not be published in any other form than as part of the publications of the colony. Up to the present no provision has been made to meet the cost of printing, but in the estimates for the coming year, it is trusted, provision will be made for the due printing and publication of this investigation. If so, they will appear in the course of the coming year, and the enormous mass of work be available for general use.

7. With regard to the theoretical calculation of these inequalities it is not necessary to say anything, as my views are well known. Most of those which require consideration have been calculated by two independent methods which have been already described in the *Monthly Notices* of the Society. So far the final reduction and numerical calculation has been suspended, so that the values deduced from the observations shall remain absolutely independent. The theoretical determination of these terms will form, therefore, a subsequent volume of the publications of the Natal Observatory as soon as the necessary funds for printing are available; and as it will be a heavy mass of mathematical printing, its cost will be much heavier than the portion of the complete whole formed by the reduction and discussion of the Greenwich lunar observations of the last 150 years.

Natal Observatory:
1903 *May* 9.

Note on the use of Peirce's Criterion for the Rejection of Doubtful Observations. By S. A. Saunder, M.A.

It would seem at first sight that when for observations made at the telescope we substitute a series of photographic measures we ought to be able to eliminate all those abnormal errors or real mistakes, such as the entry of a wrong figure, which are not con-

nplated in the Theory of Errors, but which undoubtedly do ;ur in practice, and which have led to the suggestion of various teria for the detection and consequent rejection of such abnor- il observations.

With regard to such classes of mistakes as may be supposed have most frequently occurred in the case of telescopic obser- tions, this is undoubtedly the case, for a photographic measure nich gives an abnormal result, and so comes under suspicion, ay be repeated any number of times, and any clerical error or istake in reading may be certainly detected and eliminated.

But a new possibility of error is introduced at the same time. plate is either accepted or rejected as a whole in accordance ith the general excellence or the reverse of its definition. But may well happen that a plate which gives excellent defini- on as a whole may yet have some defective images. How far is is likely to occur in star photographs, such as those taken r the astrographic catalogue, I have no experience; but it does, id I think must, happen in every photograph of the Moon. ormations near the terminator may be beautifully sharp, whilst om unsuitable illumination, or from the general brightness of district, those in other parts may be quite unmeasurable. etween these two extremes there will be an almost continuous adation, and it becomes an anxious question where to draw the ne between those formations which are to be measured and ose to be rejected. Another possible cause of error may be at the assumed positions of some of the standard points are iously wrong. Where these standard points are stars which ve been repeatedly observed with meridian instruments such rors are not likely to be great; but in an investigation such as survey of the Moon, where in our present state of knowledge e standard points have to be built up as we proceed, it is a sibility not to be lost sight of. There is too the, probably all, risk of distortion of the film.

In a recent difficulty, due to an attempt to measure two badly efined formations, I found Peirce's criterion so useful that I ought it might be of interest to call attention to it, especially s I believe that the criterion is seldom if ever employed by the ost experienced computers, at all events in this country.

The plate in question was one of those most kindly placed at y disposal by M. Loewy; it was taken at the Paris Observatory n 1899, March 22, and shows something like three quarters of he disc under morning illumination with a terminator at about - 41°. Some 300 or 400 points have been measured by Mr. Lardcastle on this plate with considerable certainty, but most of em are near the terminator, and in order to determine the con- ants of the plate it was very desirable to have some points near e west limb. Two of the best determined of such points are *Macrobius a* and *Proclus*, whose positions have been measured and 12 times respectively by Dr. Franz with the Königsberg

heliometer.* The formations were both over exposed on the plate, and Mr. Hardcastle noted at the time he made the measures that considerable uncertainty attached to them. The value of such points is, however, so great for determining the scale and orientation that I decided to include them in a group of 45 points, giving 90 conditional equations, from which the four constants of the plate were to be determined.

When the solution was completed it was found that *Macrobius a* gave a residual of 65 in ξ, *Proclus* one of 68 in η; the unit being ·00001 of the Moon's radius, so that each residual was about 0″·6. These were the greatest residuals found; they were so large as to make me uneasy about them, and yet not so large that I could unhesitatingly say that they ought to be rejected. In this dilemma I computed the value of Peirce's criterion, which gave 63 as the limit for rejection of a single observation, the mean error of a co-ordinate being 22·9. The critical value for a third observation was 54, and the next residual actually occurring was 50. The criterion thus gave me just the additional assistance I required in order to come to a decision; I rejected the two points and solved again. The mean error fell to 20·1, the value of the Moon's radius, giving the scale of the plate, was altered by 0″·06 with a probable error ± 0″·043, the orientation was altered by 33″ with a probable error ± 9″·7, the discordances in the positions of the two rejected points each rose to 74, and the residual of 50 fell to 46. The general impression left on my mind was that the solution was much improved.

The general question of the rejection of discordant observations has been discussed by Dr. Glaisher,† who strongly upholds De Morgan's view that when recognisable mistakes have been eliminated no observation should be rejected, but that when the first solution has been effected the conditional equations should be re-weighted in accordance with their residuals and solved again, the process being continued until the weights assumed for the last solution are sufficiently near to those given by that solution. How many solutions this would in general require I do not know, but it is clear that the process might be a very laborious one. In many cases its length would be practically prohibitive, and if we decide to give all the equations, either unit or zero weight, it is certain, as Dr. Glaisher points out, that we shall get a better result by excluding certain discordant observations than we should by including them.

I believe that the practice amongst computers of experience is to rely almost entirely on their individual judgment, taking into account the conditions of the observations, and drawing the line somewhere about those observations which give residuals of five times the probable error. But for those who, like myself, have a very limited practical acquaintance with least square

* *Königsberg Beobach.*, Band 38; 'Die Fig. des Mondes,' pp. 10, 11.
† *Monthly Notices*, Vol. xxxiii., pp. 391–402.

ılutions, difficult cases, like the one I have just quoted, must om time to time arise, and I cannot help thinking that others ıay be as glad as I have been to have recourse to a criterion stablished on some definite principle, which may be considered s an embodiment of that accumulated experience which we lack.

The computation of the criterion is quite a short matter with he help of such tables as those given in Chauvenet, but it is only o be effected through successive approximations by trial and rror, and in order to facilitate its application I have computed a hort table which I append to this paper.

If ϵ denote the mean error (error of mean square) as given by he least square solution, the critical residual may be denoted by x, where κ is the quantity it was the object of Professor Peirce's investigation to discover. Values of κ^2 are given in Chauvenet, as computed by Gould, for any number of conditional equations up to 60 involving either one or two unknowns. But in determining the constants of a photographic plate the number of unknowns which enter into a group of conditional equations is usually either three or four. I have accordingly computed the values of κ for these cases and for numbers of conditional equations between 10 and 100.

It did not seem necessary to make the table as elaborate as Dr. Gould's, since interpolation is easy, and the values given are, even theoretically, only approximate. The theoretical value depends upon the ratio of the two values of ϵ when the questionable observations are included, and when they are excluded; this ratio must vary in different cases, but an approximation is made by assuming that the sum of the squares of the residuals is diminished only by the squares of those given by the observations rejected. This gives the new value of ϵ a little too large and consequently makes κ a little too small. But as we are in the neighbourhood of a minimum value of the sum of the squares the difference is usually small.

Also it must be remembered that the criterion is to be considered only as a guide to the computer on whose judgment the final decision must ultimately depend.

In the following table

m denotes the number of conditional equations;

μ the number of unknown quantities;

n the number of observations it is proposed to reject.

It must be particularly borne in mind that the criterion for $n = 2$ is not to be applied unless one observation has been rejected by that for $n = 1$; that for $n = 3$, not unless two have been rejected by that for $n = 2$, and so on.

Peirce's Criterion.

Values of κ.

	$\mu = 3$.				$\mu = 4$.			
m	n				m	n		
	1	2	3	4		1	2	3
10	1·72	1·44	1·28	1·16	10	1·63	1·37	1·22
12	1·83	1·55	1·38	1·26	12	1·76	1·49	1·33
14	1·92	1·64	1·47	1·35	14	1·86	1·59	1·43
16	2·00	1·72	1·55	1·42	16	1·94	1·67	1·50
18	2·06	1·78	1·61	1·48	18	2·01	1·74	1·57
20	2·12	1·84	1·67	1·54	20	2·07	1·80	1·63
25	2·23	1·96	1·79	1·66	25	2·19	1·92	1·76
30	2·32	2·05	1·88	1·75	30	2·29	2·02	1·85
35	2·39	2·12	1·95	1·83	35	2·36	2·10	1·93
40	2·45	2·19	2·02	1·90	40	2·43	2·16	2·00
45	2·51	2·24	2·08	1·95	45	2·48	2·22	2·06
50	2·55	2·29	2·13	2·00	50	2·53	2·27	2·11
60	2·63	2·37	2·21	2·09	60	2·61	2·35	2·19
70	2·69	2·44	2·28	2·16	70	2·67	2·42	2·26
80	2·74	2·49	2·34	2·22	80	2·73	2·48	2·32
90	**2·79**	**2·54**	**2·39**	**2·27**	**90**	**2·77**	**2·53**	**2·37**
100	2·83	2·58	2·43	2·32	100	2·81	2·57	2·42

On Oscillating Satellites. By H. C. Plummer, M.A.

1. In his paper "On Periodic Orbits" * (to be quoted here *Ch.*) Professor Charlier has tried to obtain in a simple analyti manner some of the results already found by Professor Darwin his well-known memoir † on this subject (to be quoted as *I* The orbits investigated by Professor Charlier are those oscillating satellites—*i.e.* those small periodic orbits which be described in the neighbourhood of the five points where ex solutions of the problem of three bodies are known to ex Some of his results I have tried to discuss in a more general v in a paper ‡ (to be quoted as *Pl.*) in which I have considered motion of a small body in the neighbourhood of centres of lil tion, or points of zero force, in any rotating field of force. the present paper it is sought to push the analysis beyond

* *Meddelanden från Lunds Astronomiska Observatorium*, No. 18.
† *Acta Mathematica*, t. xxi. p. 99.
‡ *Monthly Notices*, vol. lxii. p. 6.

first degree of approximation previously obtained and to consider more particularly the orbits in the neighbourhood of the three collinear points of libration, especially those of families a and b, for which numerical results are to be found in *D*.

2. As far as possible the notation of *Pl.* will be retained. The equations of motion of the third mass in the most restricted form of the problem of three bodies, referred to axes rotating with the line joining the finite masses, are

$$\ddot{x}-2\dot{y}=\frac{\partial\Omega}{\partial x},\quad \ddot{y}+2\dot{x}=\frac{\partial\Omega}{\partial y}$$

where

$$2\Omega=\mu\left(r_1^2+\frac{2}{r_1}\right)+\nu\left(r_2^2+\frac{2}{r_2}\right)$$

The masses of the finite bodies are μ and ν, and the unit of mass is such that $\mu+\nu=1$. The origin is taken at the centre of gravity of the two revolving bodies, these lying on the axis of x and their distance apart being the unit of length. The unit of time is such that the angular velocity of the axes is also unity. The partial differentials of Ω with respect to x and y are: of the first order, p and q; of the second order, r, s, and t *; of the third order, P, Q, R, and S. Then if the point (x, y) is a centre of libration, for which $p=q=0$, and the coordinates of the small mass are $x+\xi$, $y+\eta$, the equations of motion may be written

$$\ddot{\xi}-2\dot{\eta}=r\xi+s\eta+\tfrac{1}{2}(\mathrm{P}\xi^2+2\mathrm{Q}\xi\eta+\mathrm{R}\eta^2)+\ \ldots$$
$$\ddot{\eta}+2\dot{\xi}=s\xi+t\eta+\tfrac{1}{2}(\mathrm{Q}\xi^2+2\mathrm{R}\xi\eta+\mathrm{S}\eta^2)+\ \ldots$$

so long as the body continues within the region where the expansions are legitimate. To the first order of the relative coordinates the solution is already known. It is

$$\xi=h\cos(mt-\alpha),\ \eta=k\cos(mt-\beta)$$

where

$$m^4+(r+t-4)\,m^2+rt-s^2=0$$
$$h^2=a^2(t+m^2),\ k^2=a^2(r+m^2)$$
$$\tan(\alpha-\beta)=-2m/s$$

These equations, found in *Pl.*, §§ 4 and 5†, leave the origin of time, depending on α, and the scale of the orbit, depending on a, arbitrary.

3. To proceed to the second approximation we may put

$$\xi=h\cos(mt-\alpha)+\xi',\qquad \eta=k\cos(mt-\beta)+\eta'$$

* The symbol t also represents the time; but this can hardly cause any confusion.

† The constant a used above is connected with the constant c used in *Pl.* the relation $a^2(4m^2+s^2)=c^2$.

where h, k are small quantities of the first order, ξ', η' of the second order. In virtue of the preceding relations among the constants, the equations of motion now become

$$\left.\begin{aligned} \ddot{\xi}'-2\dot{\eta}' &= r\xi'+s\eta'+\mathrm{U} \\ \ddot{\eta}'+2\dot{\xi}' &= s\xi'+t\eta'+\mathrm{V} \end{aligned}\right\} \quad (\mathrm{A})$$

where if terms beyond the second order be neglected

$$2\mathrm{U}=\mathrm{P}h^2\cos^2(mt-\alpha)+2\mathrm{Q}hk\cos(mt-\alpha)\cos(mt-\beta)+\mathrm{R}k^2\cos^2(mt-\beta)$$

$$2\mathrm{V}=\mathrm{Q}h^2\cos^2(mt-\alpha)+2\mathrm{R}hk\cos(mt-\alpha)\cos(mt-\beta)+\mathrm{S}k^2\cos^2(mt-\beta)$$

Hence

$$\mathrm{U}=a_1+b_1\cos 2mt+c_1\sin 2mt$$
$$\mathrm{V}=a_2+b_2\cos 2mt+c_2\sin 2mt$$

where

$$4a_1=\mathrm{P}h^2+2\mathrm{Q}hk\cos(\alpha-\beta)+\mathrm{R}k^2$$
$$4b_1=\mathrm{P}h^2\cos 2\alpha+2\mathrm{Q}hk\cos(\alpha+\beta)+\mathrm{R}k^2\cos 2\beta$$
$$4c_1=\mathrm{P}h^2\sin 2\alpha+2\mathrm{Q}hk\sin(\alpha+\beta)+\mathrm{R}k^2\sin 2\beta$$

and the corresponding equations for a_2, b_2, and c_2 are found by substituting Q, R, S for P, Q, R respectively. Then the equations (A) will be satisfied by the solution

$$\xi'=f_1+h_1\cos 2mt+k_1\sin 2mt$$
$$\eta'=f_2+h_2\cos 2mt+k_2\sin 2mt$$

provided that

$$rf_1+sf_2+a_1=0$$
$$sf_1+tf_2+a_2=0$$

and that

$$\begin{aligned} (4m^2+r)h_1+sh_2 \qquad\qquad &+4mk_2 &&+b_1=0 \\ -4mh_2 \quad +(4m^2+r)k_1+sk_2 \quad &&&+c_1=0 \\ sh_1 \quad +(4m^2+t)h_2-4mk_1 \quad &&&+b_2=0 \\ 4mh_1 \qquad\qquad +sk_1 \quad &+(4m^2+t)k_2 &&+c_2=0 \end{aligned}$$

From this latter set of four equations we obtain

$$\begin{aligned} \delta\,.\,h_1 &= -(4m^2+t)b_1+sb_2 && &&+4mc_2 \\ \delta\,.\,h_2 &= \quad sb_1 && -(4m^2+r)b_2-4mc_1 && \\ \delta\,.\,k_1 &= && -4mb_2 && -(4m^2+t)c_1+sc_2 \\ \delta\,.\,k_2 &= \quad 4mb_1 && && +sc_1 \quad -(4m^2+r)c_2 \end{aligned}$$

where

$$\delta=3(4m^4+s^2-rt)$$

4. From these results obtained by proceeding to the second order of the dimensions of the relative orbit we have two general properties which characterise the orbits of oscillating satellites :

The orbits of any family are tautochronous to this order roximation.

The mean position of the small body is displaced by an t of the second order from the corresponding centre of on.

this way it should be possible to find, with little extra e, better approximations to the relative paths of oscillating tes than the elliptic orbits discussed in *Ch.* The results in *D.* for satellites of families *a* and *b* show that tauto- sm ceases to hold at a comparatively small distance from a of libration. This fact restricts the application of (1) to mited areas, and suggests that an independent study of the ion of the period in this class of orbit would be very le.

The formulæ are much simplified when the collinear centres ation in the special problem are considered. In this case and we have for the partial differentials of Ω

$$p=\pm\mu\cdot\left(r_1-\frac{1}{r_1^2}\right)\pm\nu\cdot\left(r_2-\frac{1}{r_2^2}\right)=0$$

$$q=0$$

$$r=\mu\left(1+\frac{2}{r_1^3}\right)+\nu\left(1+\frac{2}{r_2^3}\right)$$

$$s=0$$

$$t=\mu\left(1-\frac{1}{r_1^3}\right)+\nu\left(1-\frac{1}{r_2^3}\right)$$

$$P=\pm\mu\cdot\left(-\frac{6}{r_1^4}\right)\pm\nu\cdot\left(-\frac{6}{r_2^4}\right)$$

$$Q=0$$

$$R=-\tfrac{1}{2}P$$

$$S=0$$

le for the ambiguous signs is this : For the orbits between nite masses (family *a*) we take $+\mu$, $-\nu$; for the orbits d ν (family *b*) we take $+\mu$, $+\nu$; for the orbits beyond μ y *c*) we take $-\mu$, $-\nu$. Now for comparison with *D.*, , $\nu=\frac{1}{11}$; and taking the values of r_1 and r_2 from *D.*, 8–111, we obtain :

	Family *a*.	Family *b*.	Family *c*.
r_1	0·71751	1·34700	0·94693
r_2	0·28249	0·34700	1·94693
r	13 9878	6·0955	3·1660
t	− 5·4939	− 1·5478	−0·0830
P	+65·076	−39·279	+6·822
R	−32·538	+19·639	−3·411
n	2 6082	1·6763	1·0706
n^2	6·8025	2·8099	1·1463

6. Further simplifications are effected by making $a=0$, $\beta=\frac{1}{2}\pi$. Then

$$4a_1 = Ph^2+Rk^2 = P(h^2-\tfrac{1}{2}k^2) = 4a^2a_1$$
$$4b_1 = Ph^2-Rk^2 = P(h^2+\tfrac{1}{2}k^2) = 4a^2\delta\,.\,a_2$$
$$4c_2 = 2Rhk = -Phk = 4a^2\delta\,.\,a_3$$
$$c_1 = a_2 = b_2 = 0$$

and hence

$$f_1 = -a^2a_1/r$$
$$h_1 = -(4m^2+t)a^2a_2+4ma^2a_3$$
$$k_2 = 4ma^2a_2-(4m^2+r)a^2a_3$$
$$f_2 = h_2 = k_1 = 0$$

The following numerical values result :—

	Family *a*.	Family *b*.	Family *c*.
log δ	2·89534	2·09008	1·21887
log a_1	$2\cdot16976_n$	1·49597	$0\cdot27043_n$
log a_2	9·38435	$9\cdot65902_n$	9·52077
log a_3	9·03335	$9\cdot42739_n$	9·34366
log f_1/a^2	1·02401	$0\cdot71096_n$	9·76992
h_1/a^2	−4·1352	+2·6261	−0·5487
k_2/a^2	−1·9209	+1·5800	−0·2895
log h/a	$0\cdot05840_n$	$0\cdot05055_n$	$0\cdot01333_n$
log k/a	0·65893	0·47482	0·31736

The coefficients h and k are taken of opposite sign in accordance with the equation (*Pl.* p. 9).

$$(r+m^2)h \sin(\alpha-\beta) = 2mk$$

7. Thus the equations of the three families of orbits are obtained. They are, for family *a* :

$$\xi = +10\cdot5685\ a^2-1\cdot1439\ a\cos 2\cdot6082t-4\cdot1352\ a^2\cos 5\cdot2164t$$
$$\eta = \qquad +4\cdot5597\ a\sin 2\cdot6082t-1\cdot9209\ a^2\sin 5\cdot2164t;$$

for family *b* :

$$\xi = -\ 5\cdot1400\ a^2-1\cdot1234\ a\cos 1\cdot6763t+2\cdot6261\ a^2\cos 3\cdot3526t$$
$$\eta = \qquad +2\cdot9841\ a\sin 1\cdot6763t+1\cdot5800\ a^2\sin 3\cdot3526t;$$

and for family *c* :

$$\xi = +\ 0\cdot5887\ a^2-1\cdot0312\ a\cos 1\cdot0706t-0\cdot5487\ a^2\cos 2\cdot1412t$$
$$\eta = \qquad +2\cdot0766\ a\sin 1\cdot0706t-0\cdot2895\ a^2\sin 2\cdot1412t$$

8. The next step is to connect the parameter *a* with the con-

t C of the Jacobian integral $V^2 = 2\Omega - C$. The equations esenting the orbits being of the form

$$\xi = h' \cos mt \,.\, a + (f_1' + h_1' \cos 2mt) \,.\, a^2$$
$$\eta = k' \sin mt \,.\, a + \quad k_2' \sin 2mt \,.\, a^2$$

ave at the time $t = 0$,

$$\xi_0 = h' \,.\, a + (f_1' + h_1')\, a^2 \,;\ \eta_0 = 0$$
$$\dot{\xi}_0 = 0 \,;\ \dot{\eta}_0 = mk' \,.\, a + 2mk_2' \,.\, a^2$$

ce to the third order in a,

$$V^2 = m^2 k'^2 \,.\, a^2 + 4m^2 k' k_2' \,.\, a^3$$
$$2\Omega = C_0 + r\xi_0^2 + \tfrac{1}{3} P\xi_0^3$$
$$= C_0 + rh'^2 \,.\, a^2 + \{2rh'(f_1' + h_1') + \tfrac{1}{3} Ph'^3\} \,.\, a^3$$

re C_0 is the value of 2Ω at the point of libration. There-

$$-C_0 = (rh'^2 - m^2 k'^2) a^2 + \{2rh'(f_1' + h_1') - 4m^2 k' k_2' + \tfrac{1}{3} Ph'^3\} a^3$$

Now the coefficient of a^3 herein vanishes, as can be proved iout difficulty. A useful check on the accuracy of the ibers occurring in § 7 is thus obtained, and the last equation therefore be written in the simple form

$$C_0 - C = (m^4 - rt)\, a^2$$

ch is equivalent to a formula in *Pl.* (§ 7). The numbers for three cases are these :

	(*a*)	(*b*)	(*c*)
C_0	3·65292	3·53418	3·17322
$m^4 - rt$	123·13	17·33	1·576

9. That the coefficient of a^3 in the expansion of $C - C_0$ must ish is clear from the fact that its sign would be changed by ng the initial conditions corresponding to $mt = \pi$. And the fication is easily obtained from the general relations of § 3 as olified in §§ 5 and 6. For we have

$$\frac{h'}{k'} = \frac{-2m}{r + m^2} = \frac{t + m^2}{-2m} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$
$$4rf_1' + Ph'^2 + Rk'^2 = 0 \quad \ldots \quad \ldots \quad \ldots \quad (2)$$
$$(4m^2 + r)\, h_1' + 4mk_2' + \tfrac{1}{4}(Ph'^2 - Rk'^2) = 0 \quad \ldots \quad (3)$$
$$4mh_1' + (4m^2 + t)\, k_2' + \tfrac{1}{2} Rh'k' = 0 \quad \ldots \quad \ldots \quad (4)$$

(3) be multiplied by m and (4) by $(m^2 + r)$. The difference, i account is taken of (1), becomes

$$3mrh_1' + 3(m^2 + r)\, m^2 k_2' - \tfrac{1}{4} m (Ph'^2 + 3Rk'^2) = 0$$

which again becomes when multiplied by $2h'/3m$

$$2rh'h_1' - 4m^2k'k_2' - \tfrac{1}{6}h'\,(Ph'^2 + 3Rk'^2) = 0$$

Hence by (2)

$$2rh'(f_1' + h_1') - 4m^2k'k_2' + \tfrac{1}{3}Ph'^3 = 0$$

which is the result required.

10. Four examples of orbits of family *a* are given in *D.* (pp. 233–238), the values of 11 C being 40·0, 39·0, 38·5, and 38·0. These give the numbers

$$11\,(C_0 - C) = 0{\cdot}1821,\ 1{\cdot}1821,\ 1{\cdot}6821,\ 2{\cdot}1821$$
$$\log a = 8{\cdot}06428,\ 8{\cdot}47046,\ 8{\cdot}54705,\ 8{\cdot}60356$$

Whence the following four sets of equations for the orbits result :

$$(\alpha)\quad \xi = +{\cdot}0014 - {\cdot}0133\cos mt - {\cdot}0006\cos 2mt$$
$$\eta = +{\cdot}0529\sin mt - {\cdot}0003\sin 2mt$$
$$(\beta)\quad \xi = +{\cdot}0092 - {\cdot}0338\cos mt - {\cdot}0036\cos 2mt$$
$$\eta = +{\cdot}1347\sin mt - {\cdot}0017\sin 2mt$$
$$(\gamma)\quad \xi = +{\cdot}0131 - {\cdot}0403\cos mt - {\cdot}0051\cos 2mt$$
$$\eta = +{\cdot}1607\sin mt - {\cdot}0024\sin 2mt$$
$$(\delta)\quad \xi = +{\cdot}0170 - {\cdot}0459\cos mt - {\cdot}0067\cos 2mt$$
$$\eta = +{\cdot}1830\sin mt - {\cdot}0031\sin 2mt$$

For comparison with Professor Darwin's calculations the following numbers may suffice. They give the points where the orbits cross the axis of x and the coordinates of the points for which $mt = \frac{1}{2}\tau$; for the latter the ordinates corresponding to the computed abscissæ are found by interpolation among the coordinates given in *D.*

$mt =$	0	π		$\frac{1}{2}\pi$	
	ξ_0	ξ_1	$\xi_0+\xi_1$	ξ'	η'
(α)	−·0125	+·0141	+·0016	+·0020	+·0529
D.	−·0125	+·0147	+·0022	,,	+·0530
(β)	−·0282	+·0394	+·0112	+·0128	+·1347
D.	−·0304	+·0413	+·0109	,,	+·1395
(γ)	−·0323	+·0483	+·0160	+·0182	+·1607
D.	−·0361	+·0523	+·0162	,,	+·1691
(δ)	−·0356	+·0562	+·0206	+·0237	+·1830
D.	−·041	+·060	+·019	,,	+·197

In every case ξ' is slightly less than the abscissa corresponding to the maximum ordinate in *D.*, as should be the case.

11. Two examples of orbits of family *b* are given in *D.* (pp. 239–242), the values of 11 C being 38·5 and 38·0. These give

$$11\ (C_0 - C) = 0{\cdot}3760, \qquad 0{\cdot}8760$$
$$\log a = 8{\cdot}64750, \qquad 8{\cdot}83116$$

and the two corresponding pairs of equations for the orbits are

$$(\alpha)\quad \xi = -{\cdot}0101 - {\cdot}0499\cos mt + {\cdot}0052\cos 2mt$$
$$\eta = +{\cdot}1325\sin mt + {\cdot}0031\sin 2mt$$
$$(\beta)\quad \xi = -{\cdot}0236 - {\cdot}0762\cos mt + {\cdot}0121\cos 2mt$$
$$\eta = +{\cdot}2023\sin mt + {\cdot}0073\sin 2mt$$

The results of a comparison with *D.* are given in a form similar to that used in the preceding paragraph.

$mt =$	0	π		$\frac{1}{2}\pi$	
	ξ_0	ξ_1	$\xi_0+\xi_1$	ξ'	η'
(α)	−·0548	+·0450	−·0098	−·0153	+·1325
D.	−·0551	+·0445	−·0106	,,	+·1312
(β)	−·0877	+·0647	−·0230	−·0357	+·2023
D.	−·0875	+·0679	−·0196	,,	+·1987

In both cases ξ' is slightly greater than the abscissa corresponding to the maximum ordinate in *D.*, as the above equations require.

12. Oscillating satellites belonging to the family *c* have not been investigated by Professor Darwin, and there seems to be no means of judging the accuracy of the above results for this family. The comparisons contained in §§ 10 and 11 for satellites of the families *a* and *b* seem to show a fairly good agreement, especially, as was to be expected, in the case of the smaller orbits. For the larger orbits, particularly those of family *a*, the results are by no means so good; and it may be noted that Professor Darwin himself found the orbit (δ) "exceedingly troublesome." But by going to a second approximation it is clear that a better notion has been obtained both of the mean position and shape of the orbit than was possible with the elliptic paths investigated by Professor Charlier. The results found in *Ch.* (*e.g.* p. 25) are really better than could fairly have been anticipated owing to the fact, mentioned in § 8, that the coefficient of a^3 in the development of C vanishes. Further progress in the study of the particular problem considered in the present paper seems to depend, as noticed in § 4, on a knowledge of the variation of the period and the effect of that variation on the form of the orbit.

University Observatory, Oxford:
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Expressions correctes de l'Heure et des Coordonnées des Etoiles dans le système de l'Axe instantané. Par F. Folie, Liège.

(*Communicated by Professor G. H. Darwin.*)

1. Dans le *Bulletin de l'Académie royale de Belgique* (janvier 1903) M. Darwin a démontré que, si l'on fait abstraction des forces perturbatrices, l'expression de l'heure, dans le système de l'axe instantané, renferme un terme de période eulérienne (305 j. pour une terre rigide) qui a pour coefficient $0^s{\cdot}01$ multiplié par la tangente de la latitude ; en sorte que, le même jour et au même instant, les heures déterminées en deux observatoires situés sur un même méridien à $+45°$ et à $-45°$ de latitude diffèrent entre elles de $0^s{\cdot}02$.

J'avais pensé que cette raison suffirait pour faire rejeter le système de l'axe instantané.

Mais de bons astronomes persistent à croire qu'il n'y a néanmoins pas lieu de renoncer à ce système.

Je me propose de démontrer qu'il expose à des erreurs telles qu'on doit nécessairement l'abandonner.

2. Pour cela je devrais rechercher les expressions des coordonnées rapportées à l'axe instantané dans le cas de la nature, c'est-à-dire en tenant compte exactement des forces perturbatrices.

Je me bornerai toutefois à envisager le principal effet de ces forces, la précession, puisqu'il est le seul auquel il soit nécessaire d'avoir égard en pratique.

Soient p, q, r les vitesses angulaires de la terre autour des trois axes principaux X, Y, Z ; α', β', γ' les angles de l'axe instantané avec ceux-ci, $\omega=\sqrt{p^2+q^2+r^2}$.

I. On a $\cos\alpha'=\frac{p}{\omega}$, $\cos\beta'=\frac{q}{\omega}$, $\cos\gamma'=\frac{r}{\omega}$, et $p=\gamma_1\cos\Gamma+c_1\sin\phi$, $q=\gamma_1\sin\Gamma+c_1\cos\phi$, $r=n=c^{te}$. La période de $\Gamma=n\mu t-\sigma$ est de 305 j. pour une Terre rigide.

Des équations précédentes on tire

$$\sin^2\gamma'=\frac{p^2+q^2}{n^2+p^2+q^2},$$ où le dénominateur peut se réduire à n^2 ;

d'où, en faisant $\frac{\gamma_1}{n}=\gamma_1$, $\frac{c_1}{n}=c$:

II. $\sin^2\gamma'=\gamma^2+c^2+2\gamma c\sin(\Gamma+\phi)$ et $\sin\gamma'=\gamma+c\sin(\Gamma+\phi)$.

Désignons par Γ' l'angle que la projection de l'axe instantané fait avec l'axe des X. On a

$$\cos\alpha'=\sin\gamma'\cos\Gamma',\quad \cos\beta'=\sin\gamma'\sin\Gamma'.$$

En nous bornant aux termes du premier ordre, nous pourrons écrire n au lieu de ω dans les expressions de $\cos\alpha'$ et de $\cos\beta'$, et γ' au lieu de $\sin\gamma'$. Alors

$$\gamma'\cos\Gamma'=\gamma\cos\Gamma+c\sin\phi,$$
$$\gamma'\sin\Gamma'=\gamma\sin\Gamma+c\cos\phi,$$

d'où l'on déduit aisément

III. $\Gamma'=\Gamma-c\cos(\phi+\Gamma)$, $\gamma'=\gamma+c\sin(\phi+\Gamma)$.

Abstraction faite de la précession, γ' se réduit à γ, Γ' à Γ.

3. De $$\frac{d\theta}{dt}=-p\cos\phi+q\sin\phi.$$

$$\sin\theta\frac{d\psi}{dt}=p\sin\phi+q\cos\phi, \text{ on tire}$$

$$\frac{d\theta}{dt}=-\gamma_1\cos(\Gamma+\phi) \text{ et } \theta=\theta_0-\frac{\gamma}{1+\mu}\sin(\Gamma+\phi).$$

$$\sin\theta\frac{d\psi}{dt}=\gamma_1\sin(\Gamma+\phi)+c_1\,;\ \sin\theta(\psi-\psi_0)=c_1t-\frac{\gamma}{1+\mu}\cos(\Gamma+\phi).$$

Si l'on considère le triangle EE_1F, dans lequel les arcs EF, E_1F, EE_1 appartiennent respectivement à l'équateur géographique, à l'équateur instantané et à l'écliptique, l'angle F sera γ', l'angle E_1, $\pi-\theta$, l'angle E_1, θ_1 ; le côté EF, ζ, angle compris entre le colure des solstices et le grand cercle des deux pôles ; le côté EE_1, $\psi_1-\psi$.

Ce triangle donne, en s'arrêtant aux termes du premier ordre

$$\theta_1-\theta=-\gamma'\cos\zeta,\ \psi_1-\psi=\frac{\gamma'}{\sin\theta}\sin\zeta.$$

Remplaçant θ et ψ par leurs valeurs précédentes et désignant par $\Delta\theta_1$ et $\Delta\psi_1$ les quantités $\theta_1-\theta_0$, $\psi_1-(\psi_0+c_1t)$, on a, en faisant $\frac{1}{1+\mu}$ égal à $1-\mu$:

$$\Delta\theta_1=-\gamma(1-\mu)\sin(\Gamma+\phi)-\gamma'\cos\zeta,$$
$$\Delta\psi_1=-\frac{\gamma}{\sin\theta}(1-\mu)\cos(\Gamma+\phi)+\frac{\gamma'}{\sin\theta}\sin\zeta.$$

Or $$\zeta=\Gamma'+\varphi-3\frac{\pi}{2}.$$

Si l'on remplace γ' par $\gamma+c\sin(\Gamma+\phi)$, on obtient, en écrivant

θ_1 au lieu de θ, puisqu'on se borne aux termes du premier ordre :

$$\Delta\theta_1 = \gamma\mu \sin(\Gamma+\phi) - c \sin(\Gamma+\phi)\cos\zeta,$$

$$\Delta\psi_1 = -\frac{\gamma}{\sin\theta_1}(1-\mu)\cos(\Gamma+\phi) + \frac{\gamma'}{\sin\theta_1}\sin\zeta.$$

4. Comme γ est égal à $0''.15$ environ, μ à $\frac{1}{305}$, on peut négliger $\gamma\mu$; on aurait donc, abstraction faite des forces perturbatrices $\Delta\theta_1 = 0$, $\Delta\psi_1 = 0$, ce qu'admettent les astronomes.

Mais il n'en est pas ainsi dans la nature, et l'on doit écrire

$$\Delta\theta_1 = -\gamma \sin(\Gamma+\phi) + \gamma' \sin(\Gamma'+\phi) ;$$

$$\Delta\psi_1 = -\frac{\gamma}{\sin\theta_1}\cos(\Gamma+\phi) + \frac{\gamma'}{\sin\theta_1}\cos(\Gamma'+\phi),$$

ou

$$\Delta\theta_1 = c \sin^2(\Gamma+\phi) ;$$

$$\sin\theta_1 \Delta\psi_1 = c \sin(\Gamma+\phi)\cos(\Gamma+\phi).$$

On aura alors

$$\Delta\delta_1 = c \sin(\Gamma+\phi)\cos(\Gamma+\phi-\alpha_1),$$

$$\Delta\alpha_1 = c \sin(\Gamma+\phi)\left[\cot\theta_1 \cos(\Gamma+\phi) - tg\delta_1 \sin(\Gamma+\phi-\alpha_1)\right].$$

L'erreur commise par les astronomes qui posent, avec Oppolzer, $\Delta\delta_1 = 0$, $\Delta\alpha_1 = 0$, peut donc s'élever, sur la déclinaison, à près de $0''.01$ ($0''.085$).

Si l'on considère cette quantité comme négligeable, il n'en peut pas être de même de l'erreur commise sur l'AR de la polaire, par exemple.

A l'époque actuelle cette erreur peut s'élever à $0^s.027$.

Pour λ *Ursæ Min.* elle serait de $0^s.07$.

5. Il me semble donc que le système de l'axe instantané doit absolument être rejeté, et que l'on doit en revenir à celui de Laplace-Bessel, en ajoutant à leurs formules incomplètes les termes de nutation à courte période (diurne ou semi-diurne).

Et cela avec d'autant plus de raison que, dans ce dernier système, on peut définir une heure, non pas à peu près, mais rigoureusement uniforme,* tandis que, dans celui de l'axe instantané,† M. Darwin a démontré que l'heure est sujette à des variations de même ordre et de même période que les variations de latitude, multipliées, de plus, par la tangente de la latitude

* *Revision des Constantes de l'Astronomie stellaire*, p. 93.

† "Je dois rendre à Oppolzer cette justice qu'il a défini l'heure dans un méridien *fixe* et dans l'équateur géographique," *Traité des Orbites*, p. 198.

lieu, en sorte que les heures qui seraient déterminées au même ıtant sous les latitudes de $+60°$ et de $-60°$ différeraient entre es de $0^s{\cdot}017$; de même que celles qui seraient observées à ^{h} d'intervalle en deux lieux situés sous le 60e degré de latitude.

Si l'on tient compte de la précession, la formule des variations ériodiques de l'heure donnée par M. Darwin

$$\Delta r = -\gamma tg\Phi \sin \Gamma$$

ɔit s'écrire

$$r = -\gamma' tg\Phi \sin \Gamma' = -tg\Phi[\gamma + c \sin(\Gamma+\phi)]\sin[\Gamma - c\cos(\Gamma+\phi)],$$

ı simplement, en négligeant les termes du second ordre,

$$\cot \Phi \Delta r = -\gamma \sin \Gamma - c \sin \Gamma \sin(\Gamma+\phi),$$

rmule dans laquelle le second terme, très faible, a une période urne, tandis que celle du premier est de 305 jours.

6. Dans le tableau suivant nous donnerons, quant aux ıriations eulériennes,

U) les formules usuelles (incorrectes) ;

I) les formules correctes relatives à l'axe instantané ;

L) les formules absolument rigoureuses de Laplace-Bessel ılatives aux axes principaux, l y représentant la longitude ientale du premier méridien (axe X).

Les unes et les autres se rapportent aux observations faites ans le méridien instantané ou dans le méridien fixe. Dans ce ernier cas les signes $\pm$ s'appliquent à un passage $\frac{\text{supérieur}}{\text{inférieur}}$.

A la simple inspection de ces formules on constate immédiatement que, dans ce dernier système, la nutation eulérienne disparaît entièrement dans la somme des coordonnées de deux toiles de même D à peu près, observées à quelques minutes ’intervalle, l'une au N., l'autre au S. ; que la différence de ces coordonnées, au contraire, double ces deux nutations en éliminant es autres : avantages bien précieux que n'offrent pas les formules elatives à l'axe instantané.

Si Oppolzer avait pû prévoir les modifications que l'introduction des forces perturbatrices apportait à ses formules si imples $\Delta\theta_1 = 0$, $\Delta\psi_1 = 0$, il est plus que probable qu'il eût enoncé à substituer le système de l'axe instantané à celui des xes principaux, qu'il a conservés, du reste, dans la définition de heure, ce que n'ont pas fait ceux qui l'ont suivi.

Cette définition de l'heure, base fondamentale de l'astronomie, oit être telle que l'heure soit, au même instant, la même en tous eux, et croisse uniformément avec le temps. Et une telle éfinition est impossible dans le système de l'axe instantané.

Elle n'existe que dans le système des axes principaux.

Nous n'avons pas à nous occuper des formules usuelles U), ui sont incorrectes.

Si nous comparons les formules correctes I) et L), il nous semble que, même en pratique, la comparaison est toute à l'avantage de ces dernières. Dans les unes comme dans les autres, γ et Γ doivent être déterminés empiriquement. Et ce sera d'autant plus long et plus difficile qu'il existe en réalité deux nutations initiales, l'eulérienne à période de 305 j., la chandlérienne à période de 431 j., comme nous allons le démontrer ci-dessous.

Mais les formules L) ont le grand avantage de permettre la détermination de ces quantités en éliminant toutes les autres variations (nutation et aberration) et c'est une raison de plus pour y revenir.

AR. U) $\Delta\alpha_1 = 0.$

I) $\Delta\alpha_1 = c \sin(\Gamma + l + a)\{\cot\theta \cos(\Gamma + l + a) - tg\,\delta_1 \sin(\Gamma + l)\}$

L) $\Delta\alpha = \pm\gamma\{-\cot\theta\cos(\Gamma + l + a) + tg\,\delta \sin(\Gamma + l)\}.$

D. U) $\Delta\delta_1 = 0.$

I) $\Delta\delta_1 = c \sin(\Gamma + L + a)\cos(\Gamma + l)$

L) $\Delta\delta = \mp\gamma\cos(\Gamma + l).$

Lat^{de} U) $\Phi_1 = \Phi_m + \gamma\cos(\Gamma + l).$

I) $\Phi_1 = \Phi_m + \gamma\cos(\Gamma + l) - c\sin(\Gamma + l + a)\cos(\Gamma + l).$

L) $\Phi = \Phi_m.$

H^{re} U) $\tau_1 = \tau_0 + nt.$

I) $\tau_1 = \tau_0 + nt - tg\,\Phi_1\{\gamma\sin(\Gamma + l) + c\sin(\Gamma + l + a)\}.$

L) $\tau = \tau_0 + nt.$*

7. S'il est une question d'un intérêt capital pour l'astronomie de précision, c'est bien celle de la nutation initiale. Les travaux de Chandler lui ont fait faire un pas de géant par la découverte d'une période de 431 j.

Deux illustres géomètres ont cherché à expliquer comment la période chandlérienne de 305 j., calculée pour une Terre rigide, s'est transformée en celle de 431 j. ; l'un en considérant que ce n'est pas pour la Terre entière, mais pour son écorce, qu'on doit calculer la période ; l'autre en ayant égard au renflement équatorial occasionné par la force centrifuge.

Leurs raisonnements seraient irréprochables si la période de 305 j. était déduite des moments connus C et A d'une Terre rigide.

Mais cette période a été déduite des constantes de la précession et de la nutation déterminées empiriquement pour la Terre (ou l'écorce terrestre) dans son état actuel, c'est-à-dire ayant subi l'effet de la force centrifuge.

* *Revision des Constantes de l'Astronomie stellaire*, p. 93.

Là n'est donc pas l'explication de la période de 431 j. qui existe indubitablement, mais qui ne s'est pas substituée à celle de 305 j.

Je me propose de démontrer que pour l'écorce il existe deux termes à constantes arbitraires ; la période de l'un est de 305 j., celle de l'autre doit être déterminée empiriquement.*

8. En désignant par M_x, M_y les moments des actions de l'écorce sur le noyau dans les deux plans perpendiculaires à x et à y, par A et C, A′ et C′ les moments principaux du noyau et de l'écorce dans un plan perpendiculaire à l'équateur et dans ce dernier plan, B et B′ étant supposés égaux à A et A′ ; par P et Q les moments des forces perturbatrices perpendiculaires aux axes x et y, par p, q, n les vitesses angulaires d'un point du noyau, par $p+\check{\imath}p$, $q+\check{\imath}q$, n celles d'un point de l'écorce qu'on supposera sur le prolongement du rayon du premier, les centres de gravité du noyau et de l'écorce étant censés coïncider ; les équations d'Euler s'écriront, pour le noyau

I.
$$A\frac{dp}{dt} = -(C-A)nq+P+M_x,$$
$$A\frac{dq}{dt} = (C-A)np+Q+M_y;$$

et pour l'écorce :

II.
$$A'\frac{d(p+\check{\imath}p)}{dt} = -(C'-A')n(q+\check{\imath}q)+P-M_x,$$
$$A'\frac{d(q+\check{\imath}q)}{dt} = (C'-A')n(p+\check{\imath}p)+Q-M_y.$$

Nous avons ainsi quatre équations pour déterminer p, q, $\check{\imath}p$, $\check{\imath}q$.

9. En négligeant, dans une première approximation, $A'\check{\imath}p$ et $A'\check{\imath}q$ vis-à-vis de Ap et de Aq, et faisant $A+A'=2A''$, $C+C'=2C''$, la somme des équations précédentes, prises deux à deux, donnera

III.
$$A''\frac{dp}{dt} = -(C''-A'')nq+P,$$
$$A''\frac{dq}{dt} = (C''-A'')np+Q.$$

* J'ai trouvé ces deux nutations initiales dans ma *Théorie du Mouvement de Rotation de l'Ecorce solide du Globe*, 1898. On a contesté la validité de ma démonstration. J'espère que la suivante ne donnera prise à aucune objection. J'ajouterai que j'ai trouvé en plus, pour l'écorce, un terme de nutation *générale* d'une période de 431 j. également ; il n'en sera pas question dans la présente analyse sommaire.

Ne nous occupant que des constantes arbitraires, nous aurons, en faisant

$$\frac{C''-A''}{A''}=\mu\ ;$$

IV. $$p=\gamma_1\cos(n\mu t-\sigma),\ q=\gamma_1\sin(n\mu t-\sigma).$$

La différence des équations I. et II. prises deux à deux donne, en admettant provisoirement que $\frac{C'}{A'}=\frac{C}{A}$.

V. $$\frac{d\delta p}{dt}=-\frac{C'-A'}{A'}n\delta q-M_x\left(\frac{1}{A}+\frac{1}{A'}\right),$$

$$\frac{d\delta q}{dt}=\frac{C'-A'}{A'}n\delta p-M_y\left(\frac{1}{A}+\frac{1}{A'}\right).$$

Quant aux constantes arbitraires, on tirera de ces équations, en faisant

$$\frac{C'-A'}{A'}=\mu'\ ;$$

VI. $$\delta p=\gamma_1'\cos(n\mu' t-\sigma'),\ \delta q=\gamma_1'\sin(n\mu' t-\sigma').$$

10. **Les termes dépendants des constantes arbitraires dans** les expressions des vitesses angulaires $p'=p+\delta p$, $q'=q+\delta q$ de l'écorce seront donc

VII. $$p'=\gamma_1\cos(n\mu t-\sigma)+\gamma_1'\cos(n\mu' t-\sigma'),$$
$$q'=\gamma_1\sin(n\mu t-\sigma)+\gamma_1'\sin(n\mu' t-\sigma').$$

$\mu=\frac{C''-A''}{A''}$ provient des équations III. qui sont identiquement les mêmes que celles du mouvement de la Terre solide.

La période du premier terme des deux équations VII. est donc de 305 j. environ.*

Mais $\mu'=\frac{C'-A'}{A'}$ dépend des moments d'inertie de l'écorce, qui nous sont absolument inconnus. L'empirisme seul peut le déterminer.

Et puisque M. Chandler a trouvé une période manifeste de 431 j., nous avons admis que $\frac{C'-A'}{A'}=\frac{1}{431}$.

Il existe donc pour l'écorce terrestre deux nutations initiales, l'une eulérienne, l'autre chandlérienne.

* Je dis environ parce que j'ai négligé $A'\delta p$ vis-à-vis de Ap.

11. J'en ai constaté l'existence dans de longues séries l'observations. L'amplitude des variations dans les latitudes de Greenwich de 1880 à 1891, réduites par MM. Thackeray et Turner, est de 1″·15.* En en faisant les sommes à 5 et à 7 mois le distance, elle a été réduite respectivement à 0″·77 et à 0″·845.

La série des latitudes de Poulkova, publiée par M. Ivanof, nous a conduit à une période de 430 j. environ pour la nutation chandlérienne, de 290 j. pour l'eulérienne.†

Or, et j'insiste sur ce fait qui démontre empiriquement l'influence, niée par les astronomes, de la nutation initiale en AR′, *j'ai déduit de la comparaison des observations de Struve en AR* 1824) avec celles de Lindhagen en AR également et de Peters en D (1843),‡

304·8 j. et 318·6 j. pour la période eulérienne,

447·2 j. et 460·3 j. pour la période chandlérienne.§

Les coefficients que j'ai trouvés par la série de M. Ivanof sont

chandlérien	eulérien	annuel
0″·13	0″·09	0″·08

D'après M. Chandler ils seraient

0″·16	0	0″·11

La valeur trop forte de ses deux coefficients provient de la négligence de la nutation eulérienne.

Il nous semble nécessaire que ces coefficients, ainsi que les deux périodes eulérienne et chandlérienne, soient déterminés à nouveau, puisqu'il n'a jamais été tenu compte que de l'une des deux seulement dans les recherches sur la variation des latitudes.

* *Bulletin de l'Académie royale de Belgique*, novembre 1898.

† *Bulletin de l'Académie royale de Belgique*, avril 1900.

‡ Vérification pratique des formules du mouvement de rotation de l'écorce terrestre (*Bulletin de l'Académie royale de Belgique*, octobre 1899).

§ Les observations de Struve m'ont conduit à une période de 336·5 j. intermédiaire entre celles de 305 et de 430 j. et à une constante = 0″·08 environ (*Revision des Constantes de l'Astronomie stellaire*, p. 13). Celles de Wagner (qui à fait usage des formules U), quoiqu'elles soient très précises, ont donné pour γ une valeur tout à fait insignifiante 0″·01, d'accord, du reste, avec les formules de réduction incorrectes dont il a fait usage (*Annuaire de l'Observatoire royal de Belgique*, 1890, p. 302).

Mean Daily Area of Sun-spots for each Degree of Solar Lati for each Year from 1874 to 1902 as measured on Photogr at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The following paper is an extension of one under a c sponding title communicated to the Royal Astronomical So in November 1889 and printed in the *Monthly Notices*, v pp. 10, 11. The table which follows has been formed by ta out the total areas of whole spots as expressed in millionth the Sun's visible hemisphere for each degree of solar latitude each year and dividing these by the number of days of obse tion to give the mean daily area. Plate 15 presents these n daily areas in graphical form, mean daily areas under 0·7 b omitted. In apportioning the different spots to their res tive latitudes the following rule has been observed. If heliographic latitude of the centre of any single spot, or g of spots when measured as one, showed °·5 or any higher fi in the decimal place, the entire area of the spot was take belonging to the next higher whole degree of latitude. showed °·4 or any lower figure in the decimal place the ar area of the spot was taken as belonging to the degree of lati indicated by the integral part of the number. Thus a sp latitude 7°·5 was taken as wholly belonging to latitude 8°, one at 7°·4 to latitude 7°.

The diagram and the tables bring out clearly several p liarities of the distribution of spots. First of all for the pe in question, viz. the twenty-nine years from 1874 to 1 inclusive, spots in a higher latitude than 33° were at all ti rare, and when seen were never large or long-lived. Tak them as a class by themselves they were seen irregularly, app ing at times which did not seem to bear any fixed relation to one of the four chief stages of the sun-spot cycle—minim increase, maximum, and decline. Omitting these spots in high latitudes—a term which would cover a zone 10° wid each hemisphere, from 33° to 42°, for no spots were observe a latitude greater than 42°—the years of maximum, 1883 1893, showed spots in practically every latitude between 30 and 30° S., and they were numerous from about 8° to 24° in l hemispheres. In the years following the maximum a mar tendency was shown for the spots to appear in lower latitt Thus in the periods of decline, 1885–8 and 1898–9, and in corresponding period, 1874–6, of the preceding cycle, 22° generally the highest latitude shown. In 1876, 1888, and 1

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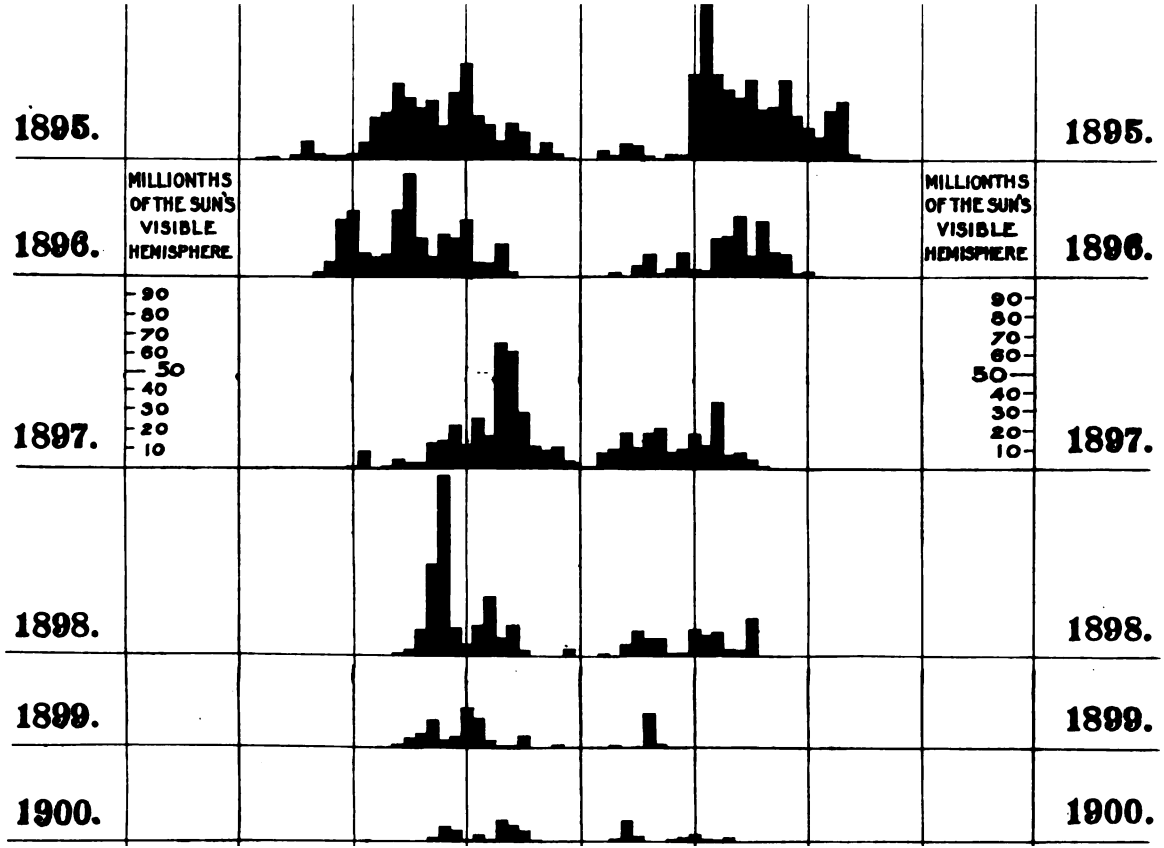

RVATORY, GREENWICH.

Mean Daily Area of Sun-spots for each Degree of Solar La for each Year from 1874 to 1902 as measured on Photog at the Royal Observatory, Greenwich.

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Mean Daily Area of Sun-spots for each Degree of Solar Latitude for each Year from 1874 to 1902 as measured on Photographs at the Royal Observatory, Greenwich.

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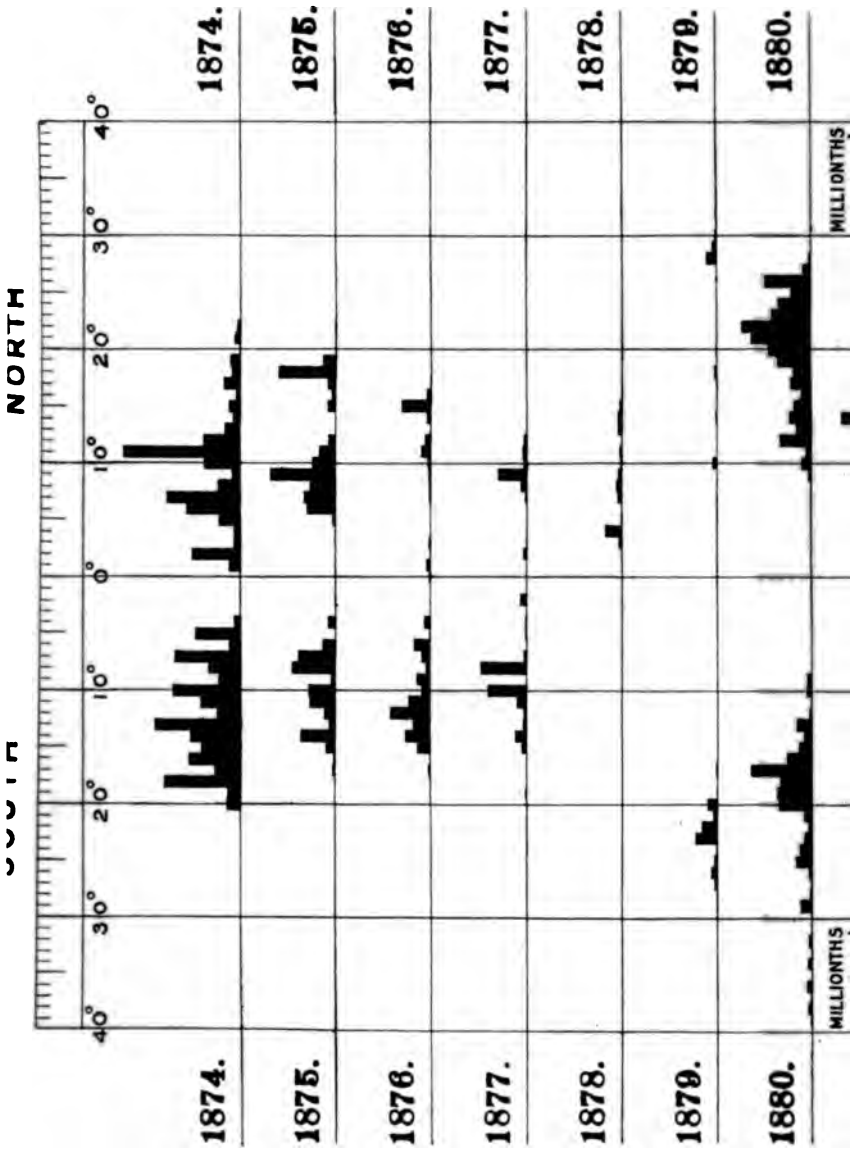
The diagram and the tables bring out clearly several peculiarities of the distribution of spots. First of all for the period in question, viz. the twenty-nine years from 1874 to 1902 inclusive, spots in a higher latitude than 33° were at all times rare, and when seen were never large or long-lived. Taking them as a class by themselves they were seen irregularly, appearing at times which did not seem to bear any fixed relation to any one of the four chief stages of the sun-spot cycle—minimum, increase, maximum, and decline. Omitting these spots in very high latitudes—a term which would cover a zone 10° wide in each hemisphere, from 33° to 42°, for no spots were observed in a latitude greater than 42°—the years of maximum, 1883 and 1893, showed spots in practically every latitude between 30° N. and 30° S., and they were numerous from about 8° to 24° in both hemispheres. In the years following the maximum a marked tendency was shown for the spots to appear in lower latitudes. Thus in the periods of decline, 1885–8 and 1898–9, and in the corresponding period, 1874–6, of the preceding cycle, 22° was generally the highest latitude shown. In 1876, 1888, and 1899,


SOUTH
NORTH
40°
30°
20°
10°
0°
10°
20°
30°
40°
1874.
1875.
1876.
1877.
1878.
1879.
1880.
MILLIONTHS
MILLIONTHS

at is to say, about one or two years before minimum, no spots ere seen outside the limit of 18° from the equator. But immeately minimum was reached the spots became more widely tended in latitude owing to the occurrence of outbreaks in gh latitudes. Thus at minimum each hemisphere, considered parately, showed two clearly defined spot-zones marked off from ch other by a broad belt in which there were no spots at all. ıis was especially marked in the years 1889 and 1890, when the ıry region, centering about latitude 15°, which when an entire lar cycle is considered is the most prolific of the whole solar rface, was completely free from spots.

Of these two spot-zones in each hemisphere the lower ppears to correspond to the series of spots of the expiring cle. This series, two years before minimum, was confined ithin the 18° limit, and would appear at minimum to seldom tain a greater latitude than 10° or 12°. The spots with a latiıde of 18° to 30° or more, on the other hand, seem to be ıe first members of the new cycle.

During the periods of increase, as 1879–81 and 1890–2, the quatorial belt was almost wholly free from spots, indicating ossibly the complete disappearance of the last members of the ld cycle. At maximum, however, the spots of the new cycle ere most widely spread, and were seen even in the near neighourhood of the equator, so that at maximum, and in the first age of the decline after it, as in 1874, 1882–6, 1893–7, the quatorial region showed its greatest activity.

The comparison of the two hemispheres shows that on the hole the southern has been the more prolific; but that the ritical points of the progress of the cycle have been marked ırlier by the northern spots than by the southern. Thus in the wo periods of increase in 1881 and 1891 the northern hemiphere had a marked advantage over the southern, and similarly ı those of decrease the drop in the spotted area in 1885 and in 396 was much more strongly shown in the northern hemiphere.

Latitude.	1888.	1889.	1890.	1891.	1892.	1893.
+40°	...	...	..	...	...	0·06
39	...	...	...	...	...	...
38	...	...	...	...	...	...
37	...	...	...	...	...	...
36	...	...	...	...	...	...
35	...	...	...	...	...	0·1
34	...	...	0·9	...	...	0·02
33	...	...	3·6	0·1	0·1	...
32	...	...	1·5	0·04	0·2	...
31	...	...	...	0·9	0·6	...
30	...	...	...	1·5	0·3	...
29	...	...	0·2	20·5	3·5	0·02
28	...	...	0·1	5·5	25·1	0·3
27	...	...	0·3	8·9	14·9	3·3
26	...	...	0·4	17·8	4·3	2·9
25	...	0·1	0·7	20·0	15·4	6·2
24	...	0·3	0·5	23·2	2·9	35·1
23	...	0·1	5·7	25·8	11·7	7·8
22	...	0·02	10·4	31·4	17·0	12·6
21	...	0·01	8·1	30·2	31·3	14·2
20	...	...	12·6	46·5	14·4	14·2
19	...	...	4·4	38·4	18·1	40·7
18	...	...	3·6	32·6	11·3	35·6
17	...	...	0·4	15·9	22·5	45·3
16	...	...	0·1	27·0	22·5	13·5
15	...	...	...	29·3	44·7	34·1
14	...	...	...	17·3	43·8	44·4
13	0·2	...	...	2·2	37·8	23·4
12	0·7	0·01	...	2·4	35·1	35·5
11	2·1	0·04	...	1·2	107·4	32·6
10	7·4	0·2	...	1·1	58·1	25·3
9	0·7	...	...	0·4	37·9	32·7
8	0·2	...	...	0·02	17·3	31·6
7	0·3	0·9	0·05	...	3·0	1·6
6	0·3	1·5	...	...	3·2	0·9
5	0·7	1·5	0·02	0·04	1·2	5·4
4	0·3	...	...	0·3	0·1	5·0
3	4·2	0·05	...	0·1	...	6·5
2	1·5	...	...	...	...	5·0
1	1·0	0·1	...	0·05	...	0·4
0	0·03	0·1	...	...	...	0·5

1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	0·04
...	...	...	...	...	0·1	...	0·04
...	...	...	...	...	...	...	...
...	...	...	...	...	...	0·02	...
0·02	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
0·1	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
0·03	...	...	...	...	...	...	...
0·05	...	...	...	...	...	0·01	0·04
0·1	...	0·03	...	...	...	...	0·1
0·1	...	...	...	...	...	...	3·3
0·7	...	...	...	...	...	...	11·0
3·2	0·1	0·02	...	...	...	...	2·6
30·7	0·1	...	...	...	...	...	2·8
25·7	...	...	...	...	...	...	0·4
11·9	0·1	0·04	...	...	...	...	0·3
16·6	2·2	0·04	0·1	...	...	...	0·8
23·4	1·5	0·2	...	...	...	...	0·04
41·5	11·4	0·2	0·3	...	...	...	0·2
27·9	12·8	0·03	0·5	...	...	...	0·1
26·3	28·5	1·2	...	...	...	...	...
41·8	10·5	4·8	20·4	0·2	...	...	9·7
32·3	31·1	8·1	3·4	0·2	0·03	...	2·8
36·7	20·7	7·5	3·7	...	2·0	...	...
44·7	19·8	34·4	12·9	...	0·7	...	...
105·3	3·1	12·1	11·6	0·7	1·3	0·03	...
44·8	3·4	17·9	14·4	...	3·5	3·6	6·2
25·1	12·5	10·1	1·7	0·1	2·0	10·9	1·3
3·0	4·0	8·7	0·9	0·5	0·8	6·4	...
0·8	1·6	20·9	9·5	2·1	...	0·2	...
1·9	11·7	18·2	9·4	17·9	0·1	...	...
7·2	5·9	11·5	13·4	0·1	2·7	...	...
8·6	0·1	18·7	6·3	0·4	11·0	...	...
2·3	2·2	10·3	0·1	1·0	1·4	...	...
4·6	0·5	8·2	1·2	0·2	...	0·3	...
0·2	0·04	1·2	...	...	0·5	0·4	...
0·1	0·02	1·3	...	...	...	...	...

Latitude.	1874.	1875.	1876.	1877.	1878.	1879.
− ° 0	...	...	0·5	...	...	...
1	...	...	...	...	...	...
2	...	...	...	3·4	...	...
3	...	...	...	0·4	...	...
4	3·1	3·6	3·1	0·7	...	...
5	23·8	0·9	0·1	0·7	...	...
6	6·0	6·6	8·3	...	...	...
7	36·3	19·7	4·1	1·2	0·1	...
8	17·1	23·0	1·9	23·4	0·1	...
9	13·7	2·5	6·7	0·3	0·1	...
10	36·7	14·2	4·5	19·9	...	...
11	21·6	13·9	11·1	4·8	...	...
12	12·5	5·7	20·6	1·2	...	0·2
13	46·0	3·1	8·8	1·7	...	0·2
14	27·2	18·4	12·9	6·1	...	...
15	21·2	4·9	6·2	2·4	...	...
16	27·8	0·8	...	...	...	...
17	14·0	1·2	0·6	...	...	0·7
18	41·0	...	...	...	...	...
19	6·8	...	...	0·5	...	0·2
20	7·3	...	...	...	...	5·0
21	...	...	...	...	...	2·1
22	...	...	...	...	...	7·7
23	...	...	...	...	...	11·2
24	...	...	...	...	...	0·5
25	...	...	...	...	...	1·7
26	...	...	...	...	...	3·0
27	...	...	...	...	...	1·8
28	...	...	...	...	...	0·04
29	...	...	...	...	...	...
30	...	...	...	...	...	...
31	...	...	...	...	...	...
32	...	...	...	...	...	...
33	...	...	...	...	...	...
34	...	...	...	...	...	...
35	...	...	...	...	...	...
36	...	...	...	...	...	...
37	...	...	...	...	...	...
38	...	...	...	...	...	...
39	...	...	...	...	...	...
40	...	...	...	...	...	...

1882.	1883.	1884.	1885.	1886.	1887.	Latitude.
5·1	0·2	0·7	0·4	4·4	1·0	— 0
4·9	0·01	0·2	3·5	8·2	1·6	1
...	...	5·7	5·2	10·1	1·1	2
...	0·05	8·9	10·6	9·4	4·7	3
1·9	2·5	5·2	22·1	10·8	3·8	4
10·0	9·9	4·2	23·1	27·7	6·4	5
3·9	17·0	14·1	14·5	11·0	3·2	6
4·7	21·0	38·1	12·2	7·2	21·4	7
4·8	52·3	56·9	21·9	12·0	39·1	8
5·4	111·5	82·3	17·4	19·6	21·3	9
19·2	122·9	59·3	35·9	25·9	10·7	10
13·3	52·2	55·8	50·8	28·1	4·3	11
20·6	23·5	42·2	32·8	16·0	7·2	12
14·1	28·5	59·9	40·1	10·2	1·0	13
38·1	39·5	33·6	53·3	16·7	1·4	14
16·8	38·3	29·7	44·2	28·8	0·8	15
8·5	61·9	19·9	43·5	9·7	0·5	16
26·8	28·8	21·2	12·5	19·0	0·9	17
44·5	23·9	17·6	14·7	19·4	2·1	18
25·2	15·7	7·2	28·4	7·4	1·4	19
29·2	3·9	4·2	12·9	1·7	0·9	20
21·1	8·1	3·0	11·9	0·8	0·01	21
74·2	66·3	0·4	14·7	0·1	...	22
37·0	31·3	2·1	1·0	0·2	...	23
10·4	23·8	16·2	0·6	0·06	...	24
0·9	4·7	6·5	0·1	...	...	25
0·5	17·5	3·7	...	0·04	...	26
8·5	3·0	2·0	...	...	...	27
40·1	3·8	0·5	...	0·01	...	28
38·2	2·9	0·06	...	...	...	29
27·8	...	0·2	...	...	...	30
...	...	...	...	...	...	31
...	...	...	...	...	...	32
...	...	...	...	...	...	33
...	...	...	...	...	...	34
...	...	...	...	...	...	35
...	...	...	...	...	...	36
...	...	...	...	...	...	37
...	...	...	...	...	...	38
...	...	...	...	...	...	39
...	...	...	...	...	...	40

Latitude.	1888.	1889.	1890.	1891.	1892.	1893.	1894.
− 0°	0·1	0·2	...	...	...	2·1	0·05
1	0·4	0·6	...	0·1	...	4·4	2·0
2	0·5	1·6	...	0·1	0·04	2·7	6·1
3	3·0	0·3	...	...	...	3·6	7·2
4	8·1	0·5	...	...	...	14·1	19·1
5	5·4	6·6	0·2	...	0·05	35·7	15·7
6	8·5	13·8	1·2	...	0·3	36·9	11·5
7	9·9	11·0	2·6	...	5·2	43·3	8·1
8	11·5	7·3	0·3	...	1·5	61·8	14·2
9	5·1	5·9	0·4	...	7·5	40·0	14·1
10	7·3	0·1	0·5	1·6	3·4	39·3	15·1
11	1·1	0·05	0·03	3·5	9·0	64·7	20·7
12	1·9	...	0·01	3·6	20·7	51·3	81·8
13	4·0	...	...	0·9	19·4	48·2	81·2
14	0·8	...	...	5·0	36·8	35·2	56·9
15	1·2	...	...	12·8	17·1	25·7	118·0
16	0·1	...	...	6·7	34·1	46·4	31·5
17	0·1	...	...	7·4	5·5	60·7	27·8
18	0·01	...	0·6	11·8	33·1	74·9	28·6
19	...	3·7	1·3	23·1	44·2	43·0	46·9
20	...	11·0	4·2	32·7	26·6	62·9	19·6
21	...	3·8	3·8	14·2	18·0	37·5	4·6
22	...	1·5	2·4	5·2	33·1	50·4	10·8
23	...	0·7	7·5	10·7	36·8	5·1	1·0
24	...	0·4	8·4	5·2	36·4	9·5	0·2
25	...	0·1	5·2	5·4	10·8	3·8	0·9
26	...	1·3	1·6	12·4	12·9	3·2	8·9
27	...	2·4	3·5	3·5	11·2	10·8	28·9
28	...	0·03	1·4	2·2	70·6	13·2	6·4
29	...	0·02	0·9	0·9	40·9	5·1	2·2
30	...	...	0·3	0·3	17·1	3·0	3·2
31	...	...	0·1	0·3	29·2	1·5	2·1
32	...	...	0·1	0·2	15·8	0·5	34·8
33	...	...	0·1	0·3	0·4	0·1	9·7
34	...	...	0·3	0·2	0·3	0·4	...
35	...	...	0·1	0·1	0·01	0·6	...
36	...	...	...	0·1	...	...	...
37	...	...	...	0·02	...	...	...
38	...	...	...	...	...	...	...
39	...	...	...	40° 0·02	...	...	...
40	...	0·03	...	42° 0·02	...	...	...

1896.	1897.	1898.	1899.	1900.	1901.	1902.
0·03	3·1	0·3	...	...	...	...
0·05	4·0	4·0	0·02	0·03	...	...
0·05	11·3	0·04	1·3	0·01	0·1	...
0·3	9·5	0·3	0·1	0·05	...	...
0·4	11·6	0·5	0·6	0·8	0·2	...
0·2	28·9	3·0	6·3	6·1	0·5	...
2·8	60·9	15·5	1·0	8·7	0·3	...
17·9	65·4	9·6	1·2	11·4	...	1·8
7·4	17·1	32·1	4·0	1·1	0·4	6·9
8·1	26·1	14·0	16·1	3·4	0·4	...
30·2	12·3	6·3	21·2	0·6	0·04	...
20·9	22·3	14·9	6·0	5·9	0·01	...
22·7	11·9	96·5	3·8	8·0	...	...
10·8	13·1	49·2	15·1	2·0	...	...
20·4	2·9	14·1	7·5	0·1	...	...
53·6	3·1	3·4	4·9	...	...	0·01
34·7	4·7	1·4	0·1	...	...	...
12·1	1·2	0·2	...	...	...	...
10·5	0·04	0·5	...	...	0·1	0·2
12·7	8·9	0·2	...	...	0·1	0·01
34·1	1·2	0·03	...	...	2·4	1·8
29·8	...	...	...	0·02	2·1	10·0
7·8	0·1	...	...	0·05	0·04	...
2·3	...	...	...	...	0·02	...
...	...	...	...	...	...	...
...	...	...	...	...	...	0·01
...	...	...	...	...	...	0·01
...	...	...	...	...	...	...
...	0·2	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	0·1
...	...	...	...	...	...	...
...	...	...	...	0·01	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	0·01	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...

Royal Observatory, Greenwich:
1903 *May* 8.

Latitude.	1888.	1889.	1890.	1891.	1892.	1893.	1894.
− 0°	0·1	0·2	...	...	...	2·1	0·05
1	0·4	0·6	...	0·1	...	4·4	2·0
2	0·5	1·6	...	0·1	0·04	2·7	6·1
3	3·0	0·3	...	...	...	3·6	7·2
4	8·1	0·5	...	...	...	14·1	19·1
5	5·4	6·6	0·2	...	0·05	35·7	15·7
6	8·5	13·8	1·2	...	0·3	36·9	11·5
7	9·9	11·0	2·6	...	5·2	43·3	8·1
8	11·5	7·3	0·3	...	1·5	61·8	14·2
9	5·1	5·9	0·4	...	7·5	40·0	14·1
10	7·3	0·1	0·5	1·6	3·4	39·3	15·1
11	1·1	0·05	0·03	3·5	9·0	64·7	20·7
12	1·9	...	0·01	3·6	20·7	51·3	81·8
13	4·0	...	...	0·9	19·4	48·2	81·2
14	0·8	...	...	5·0	36·8	35·2	56·9
15	1·2	...	...	12·8	17·1	25·7	118·0
16	0·1	...	...	6·7	34·1	46·4	31·5
17	0·1	...	...	7·4	5·5	60·7	27·8
18	0·01	...	0·6	11·8	33·1	74·9	28·6
19	...	3·7	1·3	23·1	44·2	43·0	46·9
20	...	11·0	4·2	32·7	26·6	62·9	19·6
21	...	3·8	3·8	14·2	18·0	37·5	4·6
22	...	1·5	2·4	5·2	33·1	50·4	10·8
23	...	0·7	7·5	10·7	36·8	5·1	1·0
24	...	0·4	8·4	5·2	36·4	9·5	0·2
25	...	0·1	5·2	5·4	10·8	3·8	0·9
26	...	1·3	1·6	12·4	12·9	3·2	8·9
27	...	2·4	3·5	3·5	11·2	10·8	28·9
28	...	0·03	1·4	2·2	70·6	13·2	6·4
29	...	0·02	0·9	0·9	40·9	5·1	2·2
30	...	...	0·3	0·3	17·1	3·0	3·2
31	...	...	0·1	0·3	29·2	1·5	2·1
32	...	...	0·1	0·2	15·8	0·5	34·8
33	...	...	0·1	0·3	0·4	0·1	9·7
34	...	...	0·3	0·2	0·3	0·4	...
35	...	...	0·1	0·1	0·01	0·6	...
36	...	...	...	0·1	...	...	...
37	...	...	...	0·02	...	...	...
38	...	...	...	...	...	...	...
39	...	...	...	40° 0·02	...	...	...
40	...	0·03	...	42° 0·02	...	...	...

1896.	1897.	1898.	1899.	1900.	1901.	1902.
0·03	3·1	0·3	...	...	...	...
0·05	4·0	4·0	0·02	0·03	...	...
0·05	11·3	0·04	1·3	0·01	0·1	...
0·3	9·5	0·3	0·1	0·05	...	...
0·4	11·6	0·5	0·6	0·8	0·2	...
0·2	28·9	3·0	6·3	6·1	0·5	...
2·8	60·9	15·5	1·0	8·7	0·3	...
17·9	65·4	9·6	1 2	11·4	...	1·8
7·4	17·1	32·1	4·0	1·1	0·4	6·9
8·1	26·1	14·0	16·1	3·4	0·4	...
30·2	12·3	6·3	21·2	0·6	0·04	...
20·9	22·3	14·9	6·0	5·9	0·01	...
22·7	11·9	96·5	3·8	8·0	...	...
10·8	13·1	49·2	15·1	2·0	...	...
20·4	2·9	14·1	7·5	0·1	...	...
53·6	3·1	3·4	4·9	...	...	0·01
34·7	4·7	1·4	0·1	...	...	...
12·1	1·2	0·2	...	...	...	...
10·5	0·04	0·5	...	...	0·1	0·2
12·7	8·9	0·2	...	...	0·1	0·01
34·1	1·2	0·03	...	...	2·4	1·8
29·8	...	...	...	0·02	2·1	10·0
7·8	0·1	...	...	0·05	0·04	...
2·3	...	...	...	...	0·02	...
...	...	...	...	...	...	...
...	...	...	...	...	...	0·01
...	...	...	...	...	...	0·01
...	...	...	...	...	...	...
...	0·2	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	0·1
...	...	...	...	...	...	...
...	...	...	...	0·01	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	0·01	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...

Royal Observatory, Greenwich:
1903 *May* 8.

Areas of Faculæ and Sun-spots compared with Diurnal Ranges of Magnetic Declination, Horizontal Force, and Vertical Force as observed at the Royal Observatory, Greenwich, in the years 1873 *to* 1902.

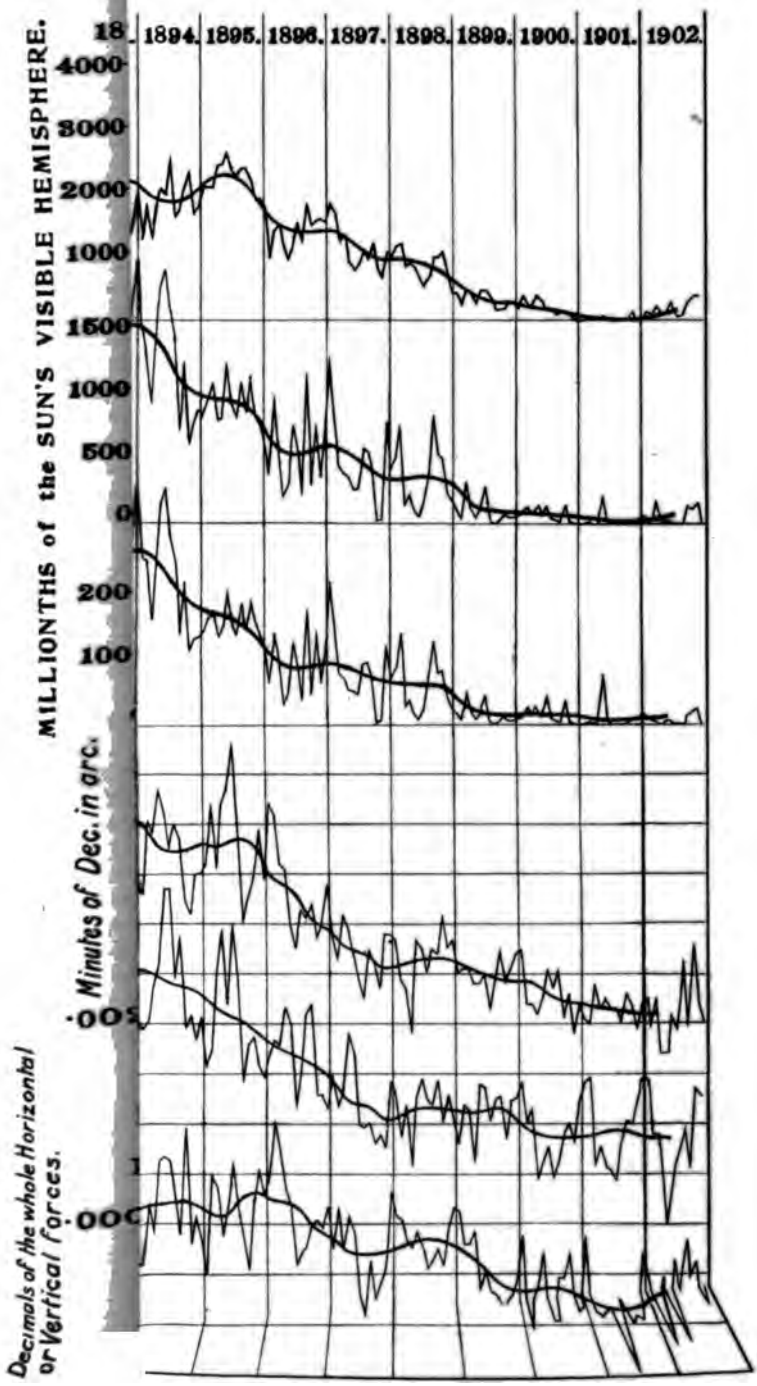
(*Communicated by the Astronomer Royal.*)

The following paper is an extension of one under a corresponding title communicated to the Royal Astronomical Society in November 1889 and printed in the *Monthly Notices*, vol. l. pp. 8–10. As in the plate accompanying that paper, which gave results up to 1888, so in Plate 16, attached to this, the three upper curves represent the areas of faculæ, whole spots, and umbræ respectively, and exhibit in a graphical form the results given on pages 106, 107, and 108 of the *Greenwich Spectroscopic and Photographic Results* for 1884, and in similar tables in the volumes for the succeeding years. For 1888 and subsequent years these results have also been communicated year by year to the Royal Astronomical Society, the figures for 1888 appearing in Table I. in the *Monthly Notices*, vol. xlix. p. 380. The mean areas for each of the three orders of solar markings have been formed by taking the means of the areas as measured upon the solar photographs, corrected for foreshortening, and reduced to millionths of the Sun's visible hemisphere for each day of observation throughout each synodic rotation of the Sun. The commencement of each rotation is defined by the coincidence of the assumed prime meridian with the central meridian, the assumed prime meridian being that meridian which passed through the ascending node at mean noon, on 1854 January 1, and the assumed period of the Sun's sidereal rotation being 25·38 days.

The ordinates for the three curves represent, therefore, the mean daily areas for each synodic rotation expressed in millionths of the Sun's visible hemisphere. The scale on which the ordinates have been drawn is five times as large for the nuclei as for the whole spots, and twice as large for the whole spots as for the faculæ, in order that the variations in each curve might be equally distinct; for the areas of the whole spots are, on the average, about five times as great as those of the nuclei, and of the faculæ rather more than twice as large as of the whole spots. A smooth curve has also been drawn for each of the three orders of phenomena, the ordinates for which correspond, at any given rotation, very nearly to the mean of the areas for the given rotation and the six preceding and following rotations, representing thirteen rotations, or nearly a year.

From 1873 to the end of 1881 only the photographs taken at the Royal Observatory, Greenwich, were available for measurement, but from 1881 December 21 the gaps in the Greenwich

MENTS AS OBSERVED AT THE


1894. 1895. 1896. 1897. 1898. 1899. 1900. 1901. 1902.
MILLIONTHS of the SUN'S VISIBLE HEMISPHERE.
Minutes of Dec. in arc.
Decimals of the whole Horizontal or Vertical forces.

series have been filled as far as possible by photographs taken at Dehra Dûn, India ; and from the beginning of 1885 by photographs taken at the Royal Alfred Observatory, Mauritius, as well. The daily record for the years 1882 to 1902 may, therefore, be considered as practically complete.

The magnetic curves are constructed from Table XIV. in the annual volumes of Greenwich magnetic and meteorological observations, giving the monthly mean diurnal range for declination, horizontal force, and vertical force. The values for vertical force are not available until the year 1883 in consequence of difficulty with the temperature correction. The results, both for horizontal force and for vertical force, are corrected for temperature. Now the magnetic diurnal ranges are subject to an annual period, being greatest in summer and least in winter, the period being one which, depending on geographical position, has not necessarily any counterpart in the solar spot variation, and which, therefore, should be eliminated in order to make comparison with the Sun-spot curves. The mean monthly values of diurnal range having been found from the results for the years 1874 to 1891, for declination and horizontal force, and from the results for 1883 to 1901 for vertical force, the differences in each case between the several mean monthly values and the mean yearly value give corrections which, applied to the monthly values for any individual year, clear out the average annual inequality. In this way the curves of diurnal range of magnetic declination, horizontal force, and vertical force given in the plate are found.

The smoothed curves are formed as follows. Assuming equality in the length of the several calendar months in each element, the mean of the first twelve values is taken, then the mean of the second to the thirteenth value, the mean of the third to the fourteenth, and so on. Finally the mean of each adjacent pair of the means so formed is taken, from which resulting value the smoothed curve is formed.

The declination range is given in angular measure, and those of horizontal force and vertical force in parts of the whole horizontal and vertical forces respectively, the scales being so arranged that equal changes of absolute magnetic force are represented by an equal length of ordinate. 1′ of declination corresponds to ·0003 of horizontal force, and to $\frac{\cdot 0003}{\tan \text{dip}} = \cdot 00012$ of vertical force, the values adopted in setting out the various scales.

Royal Observatory, Greenwich:
1903 *May* 8.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1902, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lxii. p. 378, and are deduced from the measurements of photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1902; and Table II. gives the same particulars for the entire year 1902, and the thirteen preceding years for the sake of comparison. The areas are given in two forms: first, projected areas—that is to say, as seen and measured on the photographs, these being expressed as millionths of the Sun's apparent disc; and next areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1902 the mean daily area of the whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator; together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1901 being added as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9.

The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotation are given in Greenwich civil time, reckoning from mean midnight.

No photographs have yet been received for four of the days included in the preparation of the following tables, but the director of the Mauritius Observatory has reported that photographs were taken there on those occasions, and that they have already been despatched to England. He further reported that the Sun was clear of spots upon three of the days. For the remaining day, values have been assumed for the areas and positions of the spots by taking the means of those obtained for the day preceding and for that following.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
	1901. d							
645	Dec. 14·20	28	20	122	20	11	67	26
	1902.							
646	Jan. 10·53	26	9·2	67	73	6·1	45	92
647	Feb. 6·87	26	5·8	30	48	4·2	22	60
648	Mar. 6·21	27	37	224	195	2·9	179	210
649	Apr. 2·52	26	0·0	0·0	80	0·0	0·0	92
650	Apr. 29·77	25	2·9	21	103	3·0	21	122
651	May 27·00	27	11	44	184	6·7	28	244
652	June 23·20	27	0·1	1·0	62	0·1	0·9	62
653	July 20·40	22	0·0	0·5	23	0·0	0·3	25
654	Aug. 16·62	25	0·6	3·9	29	0·4	2·6	35
655	Sept. 12·87	27	35	198	230	16	146	279
656	Oct. 10·15	27	29	181	294	20	127	326
657	Nov. 6·45	27	35	222	320	24	166	346
658	Dec. 3·76	26	0·3	5·9	314	0·3	3·9	342

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278
1896	364	127	745	1243	90	543	1410
1897	364	122	695	977	88	514	1149
1898	363	93	532	767	64	375	891
1899	364	27	159	297	18	111	337
1900	360	22	101	150	17	75	180
1901	359	14	41	23	8·6	29	29
1902	349	14	86	150	10	62	172

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	1901. d			°		°	°	°
645	Dec. 14·20	28	0·3	26·70	67	7·95	− 7·82	8·02
	1902.							
646	Jan. 10·53	26	0·0	...	45	7·41	− 7·41	7·41
647	Feb. 6·87	26	2·1	22·88	0·7	15·53	+21·58	22·63
648	Mar. 6·21	27	1·79	24·46	0·0	...	+24·46	24·46
649	Apr. 2·52	26	0·0	...	0·0	...	...	...
650	Apr. 29·77	25	2·1	25·95	0·0	...	+25·95	25·95
651	May 27·00	27	2·8	22·82	0·0	...	+22·82	22·82
652	June 23·20	27	0·9	26·08	0·0	...	+26·08	26·08
653	July 20·40	22	0·0	...	0·3	25·70	−25·70	25·70
654	Aug. 16·62	25	2·6	27·50	0·0	...	+27·50	27·50
655	**Sept. 12·87**	**27**	**7·8**	**13·06**	**6·8**	**20·95**	**− 2·80**	**16·74**
656	Oct. 10·15	27	4·0	9·88	8·7	20·72	−10·99	17·27
657	Nov. 6·45	27	16·5	14·81	1·2	20·59	+14·55	14·85
658	Dec. 3·76	26	3·4	21·23	0·5	18·95	+16·46	20·96

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1889	360	5·0	7·26	73·0	11·90	−10·68	11·61
1890	361	53·1	22·20	46·3	21·75	+ 1·73	21·99
1891	363	40·1	20·49	16·9	19·91	+ 8·52	20·31
1892	362	6·7	15·09	6·7	21·69	− 3·29	18·39
1893	360	5·17	14·91	9·41	14·26	− 3·93	14·49
1894	364	5·43	12·31	7·39	15·56	− 3·75	14·18
1895	364	5·65	14·26	4·09	12·54	+ 3·01	13·54
1896	364	2·03	13·60	3·40	14·77	− 4·15	14·33
1897	364	1·96	8·32	3·18	7·73	− 1·62	7·96
1898	363	1·10	9·82	2·66	10·77	− 4·75	10·49
1899	364	2·3	6·18	8·8	10·43	− 6·95	9·54
1900	360	2·6	6·61	4·9	8·34	− 3·12	7·74
1901	359	2·2	8·59	6·6	16·27	+ 2·82	10·37
1902	349	4·2	18·81	2·1	15·35	+ 7·38	17·65

The principal features of the record for 1902 are :—

1. The increase in area, which has been shown alike by umbræ, whole spots and faculæ, indicates that the minimum is definitely over and that the period of revival has begun.

2. For the whole spots the mean daily area has been more than double what it was in 1901, but has not been quite equal to that for 1900.

3. There has been an increase in the area of the umbræ, but this has been only slight.

4. The increase in the area of the faculæ has been very striking, especially during the last four rotations of the year.

5. Comparing the whole spots of the two hemispheres, the area for the northern has been just double that for the southern, but the rate of increase has been slightly the larger for the southern hemisphere.

6. The southern hemisphere was in a condition of practically undisturbed quiescence for eight rotations in succession.

7. The distribution of spots in latitude has been very characteristic of the beginning of a new cycle. The majority of the spots in both hemispheres were in high latitudes, extending from 17° to 28°, and there was one instance in each hemisphere of a group in a latitude considerably higher still. The equatorial region was entirely deserted, no group having a latitude of under 7° ; but there was a distinct belt of activity just beyond that limit, whilst there were none in the zone extending from 10° to 14°. Regarding the spots in each hemisphere as divided into two distinct regions by this barren zone, their areas and mean latitudes were :

	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.
		°		°
Low latitude spots ...	7·4	9·85	8·7	7·74
High „ „ ...	34·1	20·74	12·2	20·81

The highest latitude recorded was 39°.

8. The days without spots were 248 in number, as compared with 289 in 1901 ; indicating an increase of activity indeed, but much less decidedly than the comparison of areas does. The earlier rotations of the year furnished much the largest portion of these spotless days, whilst rotations 655 to 659 were the only rotations of the year in which the number of days without spots did not greatly exceed one half of the total number of days of observation.

9. The number of separate groups of spots was considerably greater than in 1901, the numbers being 14 for 1901 and 35 for 1902. Of these 35, 24 groups were in the northern hemisphere and 11 in the southern.

Royal Observatory, Greenwich:
1903 *June* 11.

The Spectra of Sun-spots in the Region B–D.

By the Rev. A. L. Cortie, S.J.

The present paper is in continuation of that published in the *Memoirs* (vol. l. p. 30–56), which discussed the observations made of the spectra of ninety Sun-spots in the years 1882–89 at the Stonyhurst College Observatory. Since that period only occasional observations of the spectra of Sun-spots have been secured—some twenty-four in all—covering the period 1890–1901. The dates of the several observations were :—1890 September 16, 1891 August 18, 30, September 3, 4, 7, 23, 28 ; 1894 November 30, December 3 ; 1896 June 15, November 5, 6, 8 ; 1898 March 11, October 8, 10 ; 1899 March 22, 24 ; 1900 March 11, October 22 ; and 1901 May 22, 23, 24. The instrument employed was the Browning automatic prism spectroscope, a dispersion of twelve prisms of 60° being in most cases used. The spectroscope was attached to the 15-inch Perry memorial refractor. The method of observation was first to pass the region B–D in review, so as to pick out the lines most affected, and then to study some particular portion of the spectrum. This latter operation is exceedingly tedious and laborious, so that a detailed study of the whole of the region B–D has only been possible on one or two occasions. In the above list of dates the most complete observations were obtained on 1891 September 3, 4, 7. For the identification of the lines the beautiful photographic maps of Mr. Higgs were used. The results of the observations are collected in the following table, which gives a list of 300 lines affected in Sun-spots in this region of the spectrum. The first column gives the wave-lengths of the lines according to Rowland's values in his "Preliminary Table of Solar Spectrum Wave-lengths." Lines observed in the spectrum of the chromosphere by Professor Young are marked with an asterisk. They are taken from his revised list (Scheiner's *Astronomical Spectroscopy*, Frost's edition, p. 423). The origins of the lines are also taken from Rowland's table, as also their intensities. Intensity 1 corresponds to a line just visible on Rowland's map, the intensity of H and K on this scale being 1,000. Below 1 the successive orders of faintness are indicated by successive zeros. The third column gives the number of times each line of the list has been observed, and the fourth its mean widening, estimated as far as possible in tenths of the normal width of the line. Lines of which the widening is 1·0 and over would correspond to the most widened lines of other observers. A column is reserved for remarks on the several lines. In former papers on this subject, and especially in the *Memoir* (*loc. cit.*), the wave-lengths of the lines were taken from the reports of the British Association. These differ by about one unit from Rowland's values now adopted.

TABLE I.

Lines between D and B widened in the Spectra of Sun-spots.

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
5890·19	D_2 Na	8	0·9	30	For discussion see notes.
91·72	A (ωυ)	1	0·5	0	
91·88	A (ωυ)			4	
93·10	Ni	3	0·3	4	Darkened once.
96·16	D_1 Na	8	0·9	20	For discussion see notes.
5900·14	A (ωυ)	1	0·3	2	
00·26	A (ωυ)			4	
05·90	Fe	1	0·2	4	
14·34	Fe	1	0·2	4	
30·41	Fe	1	0·4	6	
38·27	A (ωυ)	1	1·0	0	High Sun line. Very much darkened in spot.
46·22?	A (ωυ)	1	0 8	3	Very much darkened in spot.
52·94	Fe	2	0·8	4	
53·39	Ti			1	
56·92	Fe	2	0·5	4	
58·10	A (ωυ)	1	0·8	1	
58·46	A (ωυ)			1	
58·84	...	1	0·5	1	
66·06	Ti A?	2	0·9	2	Once much darkened in spot.
68·50	A (ωυ)	2	0·5	2	
71·56	A (ωυ)	1	1·0	1	
75·58	Fe	3	0·4	3	
77·01	Fe	3	0·4	4	
78·77	Ti	3	1·3	1	Twice the widening extended through spot into photosphere.
83·91	Fe	3	0·3	5	
85·04	Fe	3	0·3	6	
87·29	Fe	3	0·4	5	
89·51	A (ωυ)	3	0·7	0	Once unaffected in spot.
91·60	...	1	0·5	2	
96·96	Ni	2	0·5	1	
98 00	Fe	2	0·6	2	
99·92	Ti A (ωυ)	1	1·0	0	
6003·24	Fe	2	0·5	6	
6005·77	Fe	1	0·0	1	

	Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
	6008·19	Fe	4	0·5	4	
	08·79	Fe	3	0·6	6	
	12·45	Ni	3	1·0	1	
	13·72	Mn	5	0·6	6	
	16·86	Mn	5	0·6	6	
	18·52	...	1	1·0	0	
	20·23		4	0·6	2	Seen as one line.
*	20·40	Fe			4	
*	22·02	Mn	4	0·6	6	
*	24·28	Fe	5	0·5	7	
*	27·27	Fe	4	0·5	4	
	30·11	A (*uv*)	1	0·5	0	
	31·24	...	1	0·5	∞	
	34·27	A?	2	0·8	0	
	35·58	A?	2	0·8	0	
	36·69	A?	2	0·8	0	
	39·95	V	7	1·0	0	
*	42·32	Fe	3	0·3	3	
	53·91	Ni	7	1·0	0	Seen as one line.
	54·29	A?			∞	
	56·23	Fe	3	0·2	5	
	57·48	...	2	1·5	∞	
	59·20?	...	1	3·0		Seen once.
	63·01	...	7	1·0	0	
	64·85	Ti	3	1·5	∞	
*	65·71	Fe	3	0·5	7	
	77·12	...	4	0·9	∞	
	78·71	Fe	3	0·6	5	
	79·23	Fe			2	
	90·43	Fe	1	1·0	2	
*	6102·39	Fe	7	1·0	2	This group of close lines is ver difficult to separate in spot The greater part of th widening is due to the C component.
*	02·94	Ca			9	
*	03·40	Fe			4	
	03·51	...			1	
*	22·43	Ca	7	1·5	10	For discussion see notes.
	25·24	...	2	0·5	1	
	6126·44	Ti	3	3·0	1	Very black in spot once. Di placed to red once.

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
6128 12	Fe	2	0 8	3	Less intense over spot once. Young attributes to Ni.
30·34	Ni	2	0·0	1	
31·79	...	1	0·5	0	
32·07	...			0	
35·58	V	2	2·0	oo	Very black once in spot.
35·99	Cr			oo	Widening probably due to vanadium.
36·83	Fe	6	0·8	8	
37·21	Fe			3	
37·92	Fe	5	0·8	7	
41·94	Fe Ba	2	0·8	7	Not in Kayser and Runge's list of the arc lines.
42·70	...	1	0·0	1	Obliterated over the spot.
45 23	...	2	0·3	2	
47·95		1	0·8	2	
48·04	Fe			3	
49·46	...	2	0·5	2	
50·36	V	1	0·8	0	
51·05	...	2	1·5	oooo	Very faint double.
51·55	...			oooo	
51·83	Fe	2	0·7	4	
54·44	Na	2	3·0	2	Displaced to violet once.
55·35	...	1	0·0	7	Less dark over the spot.
56·24	...	1	0·2	oo	
57·95	Fe	2	0·5	5	
59·59	...	1	0·8	0	
60·96	Na	9	1·5	3	For discussion see notes.
61·50	Ca			4	
62·39	Ca	3	0·6	15	Unaffected once.
63·77	Fe	3	0·8	1	
63·97	Ca			3	
65·58	Fe	4	0·5	3	Unaffected once. Less dark over spot once.
66·65	Ca	5	0·8	5	
69·25	Ca	5	0·8	6	Darkened once.
69·78	Ca	4	0·8	7	,, ,,
70·42	V	4	0·9	cooo	
70·73	Fe Ni			6	,, ,,
6173·55	Fe	4	0·6	5	,, ,,

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
*6175·58	Ni	4	0·6	3	Darkened once.
* 77·03	Ni	4	0·6	5	„ „
80·42	Fe	4	0·5	5	„ „
83·78?	A (ων?)	1	1·0	0	In Higgs's map solar altitude 43
85·92	Fe	3	0·9	1	The British Association Catalogue line 6187·26 seem misplaced.
86·93	Ni			2	Unaffected once.
88·21	Fe	4	0·5	4	„ „
90·61	...	2	0·9	000	A faint double.
90·87				0000	
91·39	Ni	4	0·5	6	
* 91·78	Fe			9	Unaffected once.
94·63	...	2	0·5	0	
95·63	...	2	0·4	0	„ „
99·40	V	6	3·0	0	Very dark in spots twice.
99·98	...	2	1·0	0000	
*6200·53	Fe	3	0·5	6	
04·83	Ni	3	1·0	1	Darkened once.
10·90	...	1	1·0	00	
12·28	...	3	2·0	00	Faint double.
12·48	...			0000	
13·64	Fe	3	0·9	6	Widening possibly due to th vanadium line at 6214·08.
* 15·36	Fe	2	1·0	5	
* 16·57	...	4	1·0	1	Young attributes bright line t vanadium.
* 19·49	Fe	3	0·5	6	
* 21·01	Fe	2	0·6	0	
* 21·55	Fe			00	
24·20	Ni?	3	0·4	1	
24·72	V	1	1·0	000	
26·95	Fe	4	0·7	1	Obliterated over spot once.
29·44	Fe	2	0·5	1	„ „ „
* 30·94	V Fe	2	0·6	8	In the arc spectrum of iron (Kayser and Runge).
* 32·86	Fe	4	0·7	3	
33·72	...	1	1·0	0000	
37·53	...	4	0·3	3	Unaffected once. Obliterated once.
*6238·60	...	3	0·0	2	Unaffected twice. Obliterated once.

	Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
	6240·17	...	5	1·0	00	
	40·53	...	4	0·9	00	
	40·86	Fe	3	0·5	3	Once widened into penumbra.
	43·06	V	16	3·0	000	Always much widened. For discussion see notes.
	43·32	...	4	0·1	1	Unaffected three times.
	44·03	...	4	0·1	2	„ „
	46·54	Fe	4	0·2	8	„ twice.
*	47·77	...	5	0·5	2	„ „
	52·05	V	7	0·9	00	
	52·77	...	4	0·5	7	
	54·05	...			co	Close triple. Unaffected once.
	54·38		9	0·7	1	The metallic lines in this region of the spectrum generally much widened in spots.
	54·46	Fe			5	
	56·17	Fe	9	0·7	00	Double. Observed as one line in spots.
	56·57	Ni Fe			6	
	58·32	Ti	8	0·9	2	
	58·57	V	...	...	0000	
	58·93	Ti	7	0·8	3	
	59·80	...	1	2·0	00	
	61·32	Ti	6	1·0	1	
	65·35	Fe	6	0·5	5	
	66·55	...	3	2·5	000	Faint line much widened at maximum.
	67·04	...	1	1·0	0000	Faint line much widened at minimum.
	69·08	V	4	2·0	000	Faint vanadium line widened at maximum and minimum.
	70·44	Fe	3	0·2	3	Once unaffected.
	71·49	Fe	2	0·5	0	„ „
	74·17	...			000	Fuzzy set of lines in spots.
	74·87	...	6	1·5	00	Not much darker in low than in high Sun.
	75·48	A (*ωυ*)			000	
	78·30	O	1	0·3	4	Head of the Alpha group, principal line.
	79·08	O	1	0·8	2	
	79·31	O			3	
	79·95	...	2	0·5	0	Unaffected once.
	6280·11	O			2	

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
6280·60	O	4	0·9	2	
80·83	Fe			3	
82·93	Co O	5	0·7	2	
86·03	A (ωυ)	3	1·0	00	Hazy over spot once.
86·36	...			0	
87·95	O	1	2·0	1	
90·43	O	3	0·6	2	
91·18	Fe			4	
92·38?	O	4	0·4	2	Darkened once. Faint dium line at 6293·03.
95·39	O	3	0·3	3	Hazy over spots twice.
96·17	O	1	0·5	3	
98·01	Fe	2	0·4	5	
99·44	Fe O	4	0·3	3	" "
* 6301·72	Fe	4	0·5	7	
02·21	O	3	0·3	2	Unaffected once.
* 02·71	Fe	3	0·5	5	
02·98	O	1	0·6	2	
06·02	O	6	2·0	2	Generally much wid Widening seemed on side once. Once extended penumbra.
06·78	O	6	0·3	2	Genorally not affected.
10·10	O	2	0·4	2	Darkened once.
10·85	O	2	0·0	1	" "
11·45	...	1	0·0	00	
11·72	Fe	2	0·3	1	Unaffected once.
12·46	...	1	1·0	00	
12·98	...	1	1·0	000	
14·88	Ni	4	0·6	4	Darkened twice.
15·20	O			0	
* 18·24	Fe	4	0·6	6	" "
18·92	...			1	
22·91	...	4	0·6	4	" "
24·10	A (ωυ)	3	0·3	0000	Darkened once.
24·71	O			co	
27·82	Ni	2	0·2	2	
30·32	Cr	2	1·3	1	
31·07	Fe	2	0·5	2	Unaffected once.
6332·18	...	1	0·8	0	

	Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
*	6335·55	Fe	4	0·4	6	Darkened twice.
*	37·05	Fe	4	0·4	7	„ „
	39·10	Fe	4	0·4	2	„ „
	39·34	Ni			2	
	42·60	A (*sv*)	2	1·0	oooo	Hazy over spot once.
	44·37	Fe	4	0·6	4	
*	47·31	...	3	0·4	2	Unaffected once.
	50·92	A (*sv*)	1	0·8	oooo	
	55·25	Fe	3	0·3	4	
	58·90	Fe	4	0·4	6	
	61·03	Ni	2	0·8	o	Hazy over spot once.
	61·42	...	2	0·0	oooo	Hazy over spot once. Unaffected once.
	62·56	Zn	1	2·0	1	
	63·09	Cr Fe			2	
	64·58	Fe	1	0·8	1	
	64·92	...			o	
	66·71	Ni	1	0·8	o	
*	69·68	Fe	1	0·3	o	
*	71·57	Fe	1	0·5	1	
	78·47	Ni	2	0·6	2	
	80·96	Fe	4	0·7	4	Spot band observed in this position.
	83·93	...	1	0·8	o	
	84·87	...	2	0·6	1	
	85·95	...	2	0·6	o	
	88·63	...	1	0·8	ooo	Spot band observed in this position.
	92·75	...	1	1·0	o	
*	93·82	Fe	8	0·5	7	Almost reversed once. Weakened once. Chromospheric intensity 2 [C line = 100] (Young).
*	6400·22	Fe	8	0·6	8	Almost reversed once. Weakened once. Chromospheric intensity 2 (Young).
	00·54	Fe			2	
	05·98	...	3	0·9	oo	
	07·52	...	1	1·0	o	
	08·23	Fe	7	0·6	5	Darkened once.
	11·87	Fe	7	0·6	7	„ „
	15·20	...	6	0·9	1	Obliterated four times.
*	6417·13	Fe	6	0·9	1	„ „

	Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
	6420·17	Fe	6	0·5	4	
	21·57	Fe	6	0·7	7	
	21·74	Ni			000	
	31·07	Fe	6	0·5	5	Darkened once.
*	32·90	Fe?	3	0·7	1	Not in Kayser and Runge's list of arc lines.
	36·63	Fe?	1	0·8	0	
*	39·29	Ca	7	0·8	8	Darkened once.
	49·36	...	1	0·5	0	
	50·03	Ca			6	Close triplet in spots.
	50·40	Co	6	0·8	0	
	50·55	Co			0	
	55·23	Co	4	0·8	0	Darkened once.
	55·82	Ca			2	
*	56·60	...	3	0·0	5	Unaffected twice. Darkened once.
	59·12	A	1	0·5	000	
	59·90	A	1	0·8	0000	
*	62·78	Ca	7	0·8	5	
	62·97	Fe			3	Darkened once. Young doubt which component reversed Arc line of Fe at 62·9 (Kayser and Runge).
	64·90	...	1	1·0	00	
	68·12?	A	1	0·5	000	
	69·41	...	3	0·5	2	
	71·89	Ca	4	0·6	5	
	72·70	A (ωυ)	1	1·0	00	
	73·41	A (ωυ)			00	
	75·44	A (ωυ)	3	0·6	0	
	75·85				2	
	79·41	A (ωυ)	1	1·0	00	
	80·29	A (ωυ)	1	0·8	1	
	82·10	...	1	0·6	3	
	83·03	Ni	1	0·5	1	
	83·47	A (ωυ)			1	
	87·01	A (ωυ)	1	0·5	0	
	91·88?	...	1	0·8	1	
	94·00?	Ca	5	0·8	6	
*	95·21	Fe	4	0·8	8	
*	6497·13	Fe	2	0·8	4	

	Wave-lengths	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
	6499·88	Ca	3	0·9	4	
	6514·96	A (*ov*)	1	0·5	2	
*	16·31	...	1	0·5	1	
	16·86	A (*ov*)	1	0·5	2	
	17·32	A (*ov*)	1	0·5	0	
	44·14	A (*ov*)	1	0·3	2	
	46·48	Ti Fe	3	0·4	6	
*	63·06	H	10	0·0	40	C line. Generally either reversed or less dark over spots.
	64·45	A (*ov*)	1	0·5	0	
	69·46	Fe	1	0·8	5	
	72·23	A (*ov*)	2	0·9	1	
	73·03	Ca?	1	0·8	1	
	75·27	Fe	1	0·8	2	
	81·45	...	1	0·8	0	
	86·55	Ni	1	0·5	1	
	91·58?	Fe?	1	0·5	00	
	93·16	Fe	1	0·5	6	
	94·12	Fe	1	0·5	4	
	6604·84	...	1	0·8	1	
	33·99	Fe	1	0·5	2	
	43·88	Ni	1	0·5	5	
	63·70	Fe	1	0·5	3	
	6678·24	Fe	1	0·8	5	

From these observations it appears that the chief phenomena in the spectrum of Sun-spots may be classified as follows:—Widening of lines, darkening of lines without widening, displacement of lines, obliteration of lines across spots, extension of the widened appearance right through the penumbra of spots on to the photosphere, reversal of lines, hazy fringes to lines, spot-bands, while with regard to the general absorption given by the spot there occur sometimes local darkenings, as, for instance, on 1896 November 8, when such a darkening of the general absorption was observed extending on each side of the D lines for a distance equal to half the distance between them. This want of uniformity in the general absorption, as well as the hazy fringes to some lines, especially those due to sodium, and notably the D lines, as also the spot-bands occasionally seen, were treated of in a paper printed in *Monthly Notices*, vol. xlvii. No. 1. The same phenomena have been recorded in the observations tabulated above, and in the same positions, so far at least as the fuzziness

surrounding the lines of sodium are concerned. The spot-bands, too, concur at least in the case of the region in which they were seen, and in the actual position of that near λ 6380·96, with those before recorded. They were observed on 1896 November 8. The former observations of these bands were made in 1885 and 1886, and it is possible that they are characteristic of Sun-spots at the period just after maximum.

Besides the C and D lines, often reversed, the line due to calcium at 6122·43, which is also a chromospheric line, was just reversed once in the spot of 1891 September 7. Around the line was a hazy appearance in the spot, which was also observed on September 4. The two strong iron lines at 6393·82 and 6400·54, which are also chromospheric lines, were almost reversed on 1896 November 6, and considerably weakened over the spot on November 8.

With regard to the D lines, they were also reversed on 1896 November 8 and displaced. Such displacements are not unusual in these two lines, and the characteristic hazy fringes about the widened lines are generally present.

The C line of hydrogen is very rarely widened in spots, but it is either unaffected or, as is generally the case, weakened where it crosses the spot, and frequently reversed. It also suffers twistings and displacements. A careful placing of the different portions of spots across the slit has shown that the reversals are mostly due to bridges or faculous gaps in the spots; but on 1898 March 11 the line was beautifully reversed in the umbra and penumbra of a spot, and of a spindle-shaped appearance like a normal widening of a line. On this same date F was reversed similarly to C, but not so brilliantly.

The lines most frequently obliterated in spots are 6415·20 and 6417·13, while 6142·70 was obliterated once.

The prevalence of vanadium in the spectrum of Sun-spots has been treated of in a paper printed in *Monthly Notices*, vol. lviii. No. 7. The most remarkable line in the spectrum of Sun-spots in this region is the very faint vanadium line at 6243·06, which occurs among the most widened line in all Sun-spots at all periods of solar activity; sometimes even with great dispersion it is impossible to see it in the photospheric spectrum, but it stands out, and generally intensely black, in the spectrum of the spots. At times in the spots it equals in intensity the strong iron line at 6246·54; on 1894 November 30 it was more intense than the iron line; and on two occasions the widening extended through the penumbra.

In the table it will be noticed that among the widened lines are some attributed to atmospheric water vapour. In the first place the character of the widening of such lines is different in appearance from the widening observed on the metallic lines, which in the latter case is black, spindle-shaped, and sharp cut, while in the case of the water-vapour lines it is of a fuzzy appearance. Secondly, these lines occur generally in crowded

f the spectrum, so that the widening may be due, not to ıter-vapour lines, but to faint solar lines very close to ın position. At the same time the possibility of the ɔe of water vapour in the upper regions of the Sun over ots is not excluded.

› same remarks may perhaps apply to the oxygen lines ɔd widened in the *a* band. Commenting upon similar ıtions in the *a* band made at Greenwich, Scheiner (*Astro-l Spectroscopy*, Frost's edition, page 179) remarks that "it ot be forgotten that an apparent broadening of hazy bands will always occur when the background of continuous ım becomes dark." But some of the lines in the band, ı 6306·02, are sharply widened and darkened. Moreover, and Paschen have identified one triplet in the red end of ar spectrum as due to oxygen.

› relative importance of the various elements, represented r lines in this portion of the spectrum, in the spectra of ots is shown in the following table.

› first two columns give the total number of lines and total r of observations of such lines for each element; the third gives the mean widening; the fourth the mean intensity lines, individual intensities below o on Rowland's scale reckoned as negative; and the remaining columns the · of bright lines seen in the chromosphere and the atomic of each element.

TABLE II.

Relative Widening of Lines of each Element.

ıent.		Total Number of Lines.	Total Number of Observations.	Mean Widening.	Mean Intensity.	Bright Lines. Chromosphere.	Atomic Weight.
n ...	...	11	58	3·52	− 0·5	1?	51·3
m ...	...	3	5	1·72	+ 0·7	0	52·2
...	...	4	27	1·26	13·8	4	23·0
...	...	9	30	1·15	1·6	0	50·0
...	...	12	66	0·99	6·8	5	40·0
...	...	4	21	0·78	+ 0·5	...	58·7
...	...	22	73	0·66	2·3	2	58·7
...	...	20	57	0·66	2·0	...	16·0
se	...	3	14	0·60	6·0	1	55·0
...	...	97	310	0·58	4·2	33	56·0
ı ...	...	24	66	0·48	2·1	8	...
ı and faint		37	79	1·06	−1·0		...

preponderating importance of vanadium in the spectrum ·spots is evident from this table, and yet its lines are very ı the normal solar spectrum and but one is doubtfully in the spectrum of the chromosphere. Passing over

chromium, of which element only three lines occur in this part of the spectrum, and sodium, which has four lines, the next important element is titanium, which has no corresponding bright lines in the chromosphere. It may be safely asserted that faint lines of vanadium and titanium occur among the most widened lines in the spectrum of Sun-spots in the region under discussion at all periods of solar activity. The calcium lines, though strong lines and coincident in five cases out of twelve with bright chromospheric lines, are generally well widened. There is not much variation in the widening at different epochs, though it is slightly more marked at the minimum.

Of the ninety-seven lines attributed by Rowland to iron in this part of the spectrum thirty-three, or about one-third, occur in Young's list of bright chromospheric lines. Of these thirty-three lines, again, twenty-six are found in Kayser and Runge's list of lines in the arc spectrum of the metal. Hence we may infer that the lines widened in spots which are also bright in the chromosphere are mainly arc lines. The question at once arises as to whether there is any difference in the behaviour of these special arc-spot-chromosphere lines in Sun-spots from the other lines which are also affected in spots. A list of these special lines was made and their mean intensity in the Fraunhofer spectrum, and their mean widening in spots was obtained. The numbers are 4·5 and 0·59, compared to 4·2 and 0·58 when all the lines of iron are averaged. Therefore there would appear to be no difference in the behaviour of such lines treated as a whole from the other iron lines. The iron lines, and in general the more prominent metallic lines, were more pronounced in the spectra of spots observed in the minimum years 1898, 1899, and 1900; but there was no displacement by them of the faint lines of unknown origin, nor more particularly of the vanadium and titanium lines in these spots. In this part of the spectrum at least there is no evidence of "crossing points" between iron lines and faint lines, and no evidence at all of change in the materials that constitute a Sun-spot. The spectrum of a Sun-spot is a very complex phenomenon in which the change in the relative widenings of lines is of minor importance when compared to the constancy of the more characteristic appearances.

Stonyhurst College Observatory:
1903 *June* 8.

robable relationship between the Solar Prominences and na. By William J. S. Lockyer, M.A. (Camb.), Ph.D. t.), F.R.A.S., Chief Assistant, Solar Physics Observatory.

Introduction

recent communication * to the Royal Society, Sir Norman and I gave the results which had been deduced from e investigation of the percentage frequency of prominences mined from observations made by Secchi and Tacchini e, and Ricco and Mascari at Catania and Palermo.

ras there shown that the chief centres of prominence ndicated movements in heliographic latitudes, the general y of these being in a direction towards the solar poles, towards the equator as is the case with the spots. on was also drawn to the fact that these centres of nce activity were not restricted to narrow zones like s, which only occur between the latitudes $\pm 5°$ and $\pm 35°$, t at times they were numerous in such high latitudes as nd even higher.

object of the present communication is to give an account results of a general survey regarding the connection the changes of position of these centres of prominence nd the various forms of the corona as observed during ipses.

as been suggested, and the idea is generally accepted, various forms of the solar corona are intimately con- rith the variation in the spotted area of the Sun's surface. nerally speaking, at about the epochs of Sun-spot maxima, na is apparently very irregular in shape, there being none of the exquisite tracery at the Sun's poles which lent at the epochs of Sun-spot minima, while the streamers confined to mid-solar latitudes and the region nearer the than they are at the minima.

facts that Sun-spots do not appear nearer the poles than $\pm 35°$, and that large coronal streamers and prominent sometimes situated in much higher latitudes than these, t times very near the poles of the Sun, and consequently he regions of spot activity, suggested that the occurrence inences, very important factors in the mechanism of the nosphere, might be closely connected with them.

Classification of Coronas.

the present general inquiry the forms of the coronas re been observed since the year 1857 have been divided e main types, and this classification, which is not new,†

. *Soc. Proc.*, vol. 71, p. 446.

r *Physics*, Lockyer (Macmillan & Co., 1874), p. 278 *et seq.*; also

is one into which most of the coronas, with the exception of two, namely 1865 and 1885, can be easily placed.

Since the forms of coronas are dependent chiefly on the positions of the coronal streamers, the three different types here adopted refer in the main to the positions of these streamers in relation to the solar equator and poles.

In the first or "polar" group, as it has here been called, since streamers are found near the solar poles, all those coronas are included which seem to have no regular form. The typical features of this group are that the polar rifts are absent, being replaced to a great extent by streamers at, or very close to, the poles, and the streamers are numerous in nearly all solar latitudes; also there is no definite equatorial extension.

To this class the following coronas belong: 1860, 1870, 1871, 1882, 1883, and 1893.

In the third or "equatorial" group, since the streamers are chiefly equatorial, the form of the corona is very regular. The polar rifts have a large spread in latitude and are well defined, while the large streamers are restricted to the regions near the equator; in fact, the great equatorial extensions are best seen in this type. This form generally takes the shape of a "wind vane," and is often referred to as such. The coronas which come into this category are those of 1867, 1868, 1878, 1889 Jan., 1889 Dec., 1900, and 1901.

The second group of this classification may be termed the "intermediate" type, as the streamers are about half-way or intermediate between the poles and the equator. In this group the polar rifts are present, but they are not so extensive in latitude as in the "equatorial" class. The coronal streamers also approach nearer the polar regions than in the "equatorial" class, but not so close as in the "polar" group, while the equatorial extensions are not in such great evidence. Generally speaking this form of corona is due to a large streamer in each quadrant, which gives the corona the appearance of a square, hence the name "square corona."*

The coronas which fall under this heading are 1858, 1869, 1874, 1875, 1886, 1887, 1896, and 1898. It may be stated that the "polar" and "equatorial" coronas are always followed by an "intermediate" type, the order being polar, intermediate, equatorial, intermediate, polar, &c.†

The "intermediate" type may sometimes approach in form a "polar" or an "equatorial" type, according as the epoch of the

Bull. de l'Académie Impériale des Sciences de St. Pétersbourg, 5e. Série, vol. vi. 1897, Hansky.

* *Solar Physics*, p. 276.

† It may be here remarked that the "intermediate" type between an "equatorial" and "polar" type has only once (1869) been recorded during the period here under investigation, and this is due to the absence of eclipses during the two short available periods since that date—namely, 1879–1881 and 1890–1892.

occurrence of the eclipse occurs nearer or farther from the epochs of occurrence of polar prominences.

Further, the "intermediate" type preceding a "polar" type will differ to some extent from one immediately following a "polar" type, because the latitudes of the centres of prominence action in each case are different, as can be seen from the accompanying plate.

Two coronas which have not yet been classified are namely those of 1865 and 1885. The former of these is of a type between the "intermediate" and "equatorial," while the latter falls between the "polar" and "intermediate" groups.

The Method of Inquiry.

The first natural and crucial test to apply, in order to determine whether there was a connection between prominences and the different forms of the corona, was to inquire at what epochs the coronal streamers were situated nearest the solar poles, and whether these were coincident with those times when the prominences were most numerous in those regions.

If this relationship were found to hold good, the next step was to see if it were possible to connect the two other main types of coronas, with the other conspicuous prominence changes.

The comparison for the first test showed that the only five "polar" coronas recorded since the year 1869, when prominence observations were commenced, occurred at those epochs when the prominences attained their highest latitudes.

This satisfactory result indicated a very probable cause and effect between prominences and the coronal streamers, for the region considered was quite outside the zone of the spots, and therefore independent of them.

It was next found that the other two types of coronas were closely associated with the number and latitudes of the centres of prominence action. Thus the "equatorial" type only occurred when there was *one* definite centre of prominence action in each hemisphere, while the "intermediate" type has been recorded at those times when *two* centres of action in each hemisphere were in progress.

The accompanying illustration (Plate 17) shows the relationship between the Sun-spot curve for both hemispheres together, the latitudes of the centres of action of the solar prominences for each hemisphere, explained in detail in a previous communication,* and the times of occurrence of all the eclipses that have occurred since the year 1857. When two eclipses of the same type occur in the same, or two successive years, they have been inserted either one above the other or obliquely to avoid overcrowding. A curve is also drawn through the different types, showing their relation to the Sun-spot curve.

* *Roy. Soc. Proc.*, vol. 71, p. 447.

Since the systematic prominence observations only commenced in the year 1872, the dotted portions of the curves previous to that date are intended only to give a rough idea of the variations as based on a general repetition of the observations of 1872 to 1885.

Fortunately for the present inquiry Respighi* made some very valuable prominence observations during the years 1870, 1871, and 1872, which are sufficiently numerous to indicate the positions of the centres of prominence activity for these years. These showed that during the years 1870 and 1871 there were two well-marked prominence zones in each hemisphere, and that the latitude of one of the zones was very high. The positions of these zones are indicated in the accompanying plate by the small circles against these years, and they agree well with the dotted curves representing the probable conditions as might have been expected from subsequent observations.

The different types of corona are plotted in three different horizons in the order "polar," "intermediate," and "equatorial," and the symbols adopted for each—namely, small circles with eight rays for the first, four rays for the second, and two rays for the third—are inserted at the epochs of their occurrence, according to the general time-scale for all the curves.

The continuous and broken vertical lines denote the epochs of the Sun-spot maxima and minima, as determined from a discussion of spots recorded on both hemispheres of the Sun.

The Results of the Comparison.

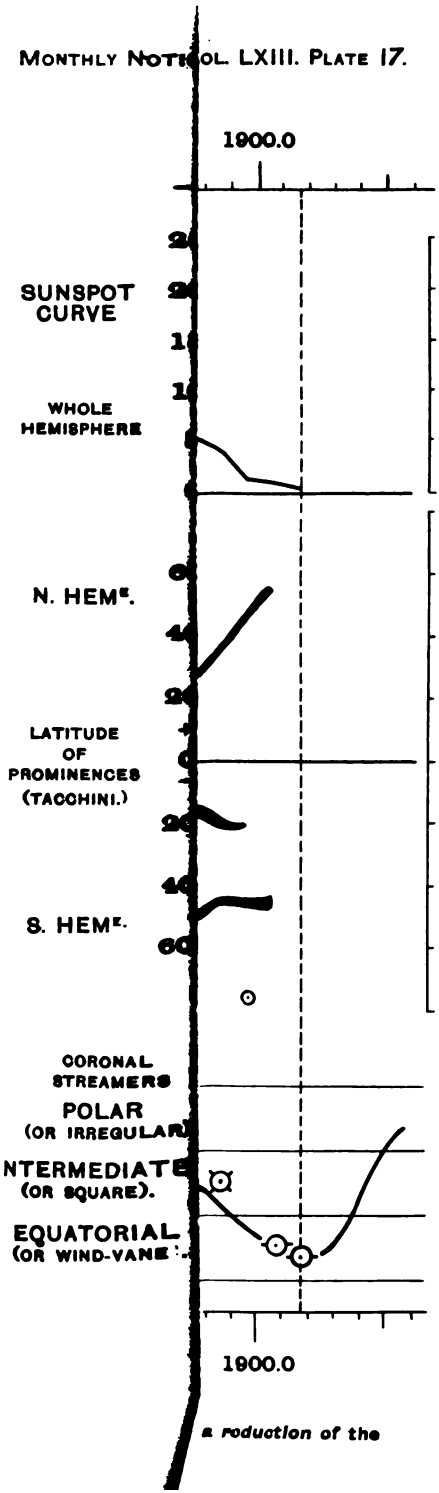
At the first glance it will be observed that the three types of the corona, as seen from the curve drawn through them, follow the Sun-spot curve very closely—that is, that at about the times of the maxima of Sun-spots, the "polar" type is present; at the minima, the "equatorial" type; and at the intervals between these, the "intermediate" type.

Although the Sun-spot curve thus affords a means of predicting in a general manner the epochs about which any of these types will occur, such a small restricted zone which the spots occupy excludes the idea of their presence being responsible for such widely distributed coronal phenomena.

The prominence curve, on the other hand, not only provides us with a more accurate method of forecast, but such phenomena can account for the changes of position and form of the coronal streamers.

By examining the prominence curves in relation to the three different types of coronas from the year 1869, this connection is seen to be very close. Thus, during the years 1870 and 1871, there were two centres of prominence action in each hemisphere, one of which was in high latitudes, and the coronas for that period

* *Solar Physics*, Appendix II. p. 654.



a reduction of the

ere of the "polar" type. From the year 1872 to 1877 there ere two centres of prominence activity in each hemisphere, both a comparatively low latitudes, and the two eclipses during the eriod, namely 1874 and 1875, were of the "intermediate" type. he next eclipse, 1878, occurred when only one centre of action as in existence, and the form of the corona was of the "equaorial" type.

As these centres of prominence action reached their extreme olar limits (about ± 80°) and a new centre had in the meanhile commenced in lower latitudes (± 25°) the eclipses of 1882 nd 1883 were of the "polar" type.

The next two eclipses, of 1886 and 1887, which were "intermediate," occurred when there were again two centres of rominence action in each hemisphere, but none near the poles. Vhen the centres became single, as they did in the years 1889, 890, and 1891, the two coronas observed in the year 1889 were f the "equatorial" type. With the movement of these centres o high latitudes in the years 1892, 1893, 1894, the eclipse of 893 was of the "polar" type.

The two eclipses of 1896 and 1898, which were "intermediate" a type, occurred when there were two chief centres of prominence ction, while the two most recent eclipses of 1900 and 1901 were ood examples of the "equatorial" type, and were concurrent ith only one centre of prominence activity in each hemisphere.

If the eclipses observed between 1856 and 1870 be compared ith the dotted prominence curves for the same period, it will be een that a similar connection seems to exist between the latitudes f the centres of action of the prominences and the three types of oronas.

The Duration of Prominence Action and the Resulting Coronal Streamers.

It may here be remarked that if the prominences, which are cknowledged to be uprushes of incandescent matter into the pper regions of the solar atmosphere, are the cause of the oronal streamers (and the evidence seems to support this idea), nd consequently responsible for the existence of the coronal treamers, and therefore of the shape of the corona, then the atter should alter their forms and positions not quickly but radually, following the slow changes of the latitude and intenity of the prominence centres of action. It is the *sum total of rominence action* in the different zones which produces the large oronal streamers, and not any particular prominence at any paricular moment; it is for this reason that the form of the corona s not a fleeting phenomenon changing every minute or hour, but asting over several months, and sometimes as much as a year or nore. That the general form of the corona does undergo comaratively slow changes, is borne out to a great extent by the imilarity of coronas which are observed at eclipses which occur

close together, such as those in 1900, 1901, the two eclipses in 1889, &c.

It may be suggested that the continued action of a centre of prominence disturbance in one latitude, extending over the greater part of a year or longer, would undoubtedly result in the formation of a large coronal disturbance, and form the locus of origin of a streamer situated in that region. It is also possible that this long-continued action might also disturb the solar atmosphere to such an extent that the coronal streamer might exist for a short time, even after the prominence action in this region had ceased.

The prominence curves here illustrated are determined from values which represent the mean prominence condition throughout a year. At any one moment therefore, say, during an eclipse, the prominences visible on the limb need not necessarily be situated in those particular latitudes as shown on the curves, but the probability would be that on the average they would be found near there. The non-coincidence of the position angle of a long coronal streamer with that of a large prominence is not necessarily a criterion that prominences as a whole do not cause the former.

The Structure and Formation of Streamers.

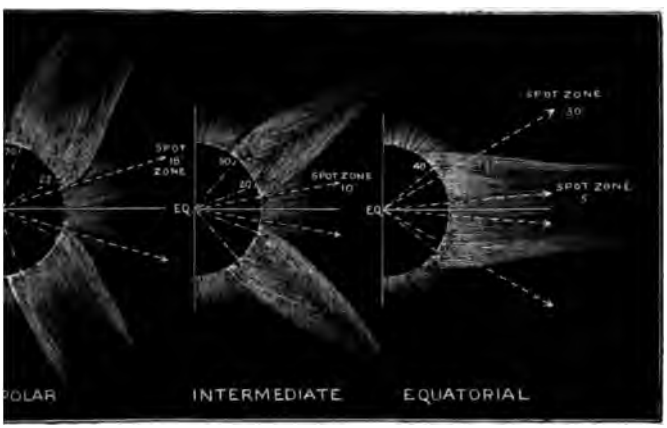
It is of great interest to briefly note the connection between the centres of prominence action when either two or one of them exist in each hemisphere. In the first place, a well-defined large coronal streamer apparently originates, as many photographs indicate, not from disturbances at the *centre* of its base, but at the two ends. Such a streamer is generally made up of groups of incurving structure, termed by Ranyard * "synclinal" groups, and this structure is in many cases very distinct. When there are *two* centres of prominence action in one hemisphere, the coronal disturbances resulting from each trend towards each other and constitute a large streamer with an apparent "arch" formation. If the two centres of prominence action exist in comparatively mid-latitudes, one large streamer is formed in each quadrant, and the form of the corona is of the "intermediate" or "square" type.

When one of the centres is near the region of the poles, and the other in comparatively low latitudes, the tendency is still for the two disturbed coronal regions to trend towards each other, but they constitute either a large streamer of an "arch" formation nearer the solar poles with a very extended base, or two separate streamers.

With *one* centre of action of prominences in each hemisphere, the resulting coronal disturbances in both hemispheres curve towards the solar equator and form apparently a large equatorial streamer: the "equatorial" type of corona is here formed.

* *Mem. R.A. Soc.*, vol. xli. p. 486.

The accompanying sketches illustrate in diagrammatic form general relationships between the latitudes of the spot es, the latitudes of the centres of action of the promi-ces, and the suggested resulting positions and origin of cture of the coronal streamers for each of the three types of nas here discussed. It will be noticed that in the case of "polar" and "intermediate" types, when the Sun-spots are ierous, the zones in which they occur have apparently little iection with the coronal streamers. When the latitudes of spot zones do approximate more nearly to the bases of the nal streamers, as in the "equatorial" type, and might be idered as being the origin of their existence, the spots at e epochs are near a minimum—that is, are very few and small ze and have the least power of action.



am showing by short radial lines the positions of the centres of promi-nce action in relation to the chief features of individual coronal streamers id the general forms of the corona. The positions of the Sun-spot zones e indicated by the longer radial lines. The three types of coronas are ire illustrated.

n conclusion, I wish to express my thanks to Mr. W. H. ley, of the Royal Astronomical Society, for his kindness in ering numerous questions relating to different coronas with h he was familiar.

Conclusion.

The following is a summary of the conclusions arrived at in preceding paper :—

. The "forms" of coronas may be grouped generally into classes, here named "polar," "intermediate," and "equa-l," according as the streamers appear near the solar poles, in latitudes, or about each side of the equator.

2. The sequence of these forms, if sufficient numbers of eclipses occurred, should be equatorial, intermediate, polar, intermediate, equatorial, &c.

3. The various forms of the corona are closely connected with the positions (as regards latitude) of the centres of action of the solar prominences.

4. The coronas of the "polar" or irregular type occur about the times when the prominences are most abundant near the solar poles.

5. The "equatorial" coronas occur when there is *one* centre of prominence action (about latitude $\pm$ 45) in each hemisphere.

6. The "intermediate" type is produced by two centres of prominence action in each hemisphere, but neither centres near the poles.

7. The peculiar "arched" form of some streamers is produced by the action of two zones of prominences situated near the extremities of their base.

8. Sun-spot activity has apparently no *direct* connection with the production of the coronal streamers.

Experiments as to the Actuality of the "Canals" observed on Mars.

By J. E. Evans and E. Walter Maunder.

The experiments described in the following paper were undertaken in order to ascertain whether the impression of a network of fine lines, such as forms what is now known as the "canal system" of *Mars*, could be produced upon entirely unbiassed observers without those lines having a real objective existence; and, should this prove to be the case, to find out the conditions most favourable for the creation of such an impression.

The experiments were made in the following manner. A circular disc, varying according to circumstances from 3·1 to 6·3 inches in diameter, was given to a class of boys to sketch. The boys in the class were usually twenty in number, and were seated at various measured distances from the disc. These distances varied in the extreme from 15 feet up to 62 feet, but more generally from about 17 feet to 38 feet. The boys were all supplied with a piece of drawing-paper upon which a circle 3 inches in diameter had been described, and were instructed to fill in that circle with all the details which they could perceive upon the disc. No hint was given them that they ought to see lines or dots or any other form of marking; they were simply urged to draw all that they could see and be sure of, each for himself, without noting what his neighbours were drawing. They were carefully watched during the experiment, and there can be no doubt at all that the drawings were independent; indeed, the internal evidence of the drawings themselves is sufficient to prove

the point. The room used had a glass roof, affording excellent light; and care was taken to hang the diagram in a position free from glare or shade.

The first series of experiments was made on 1902 July 1, the last on 1903 May 22, the great majority having been made in the spring of the present year.

The boys employed in the experiments were from the Royal Hospital School, Greenwich. Their ages ranged from twelve to fourteen for the most part; a few were either a little older or a little younger than these ages. All of them were wholly and entirely ignorant of the appearance of *Mars* in the telescope, and of the discussions which have taken place as to the markings on his surface. They were simply shown, what was to them, an odd-looking figure, and were told to reproduce it as well as they could.

Several suggestions have been made at different times to account for the curious network of straight lines first seen upon *Mars* in any considerable development by Professor G. V. Schiaparelli during the opposition of 1877. These may be summarized as follows:—

(1) The "canals" are not really lines at all, but are the boundaries of districts differing in colour or brightness from the surrounding surface. This suggestion was due to the late Mr. N. E. Green (*Journal of the British Astronomical Association*, vol. i. pp. 110–113; *see* also *Observatory*, vol. v. pp. 135–137 and p. 143).

(2) They are "only the summation of a complexity of detail, far too minute to be ever separately discerned." This suggestion was made by Mr. Maunder (*Knowledge* for 1894 November, pp. 249–252, and for 1895 March, p. 58); also in somewhat different terms a few years later by Signor V. Cerulli (*Nuove Osservazioni di Marte: Saggio di una interpretazione ottica delle sensazioni areoscopiche*).

(3) The canals are purely subjective, and are suggested by the outlines of the "continents" or bright regions of the planet upon which they are seen. This is in effect the inference from Mr. B. W. Lane's experiments described in *Knowledge* for 1902 November, pp. 250, 251.

There will be no need to give in detail all the experiments made, as the results in each particular class were of the same character whatever the part of the planet represented. The region especially chosen was that called in Mr. Green's chart of 1877 (*Memoirs, R.A.S.*, vol. xliv.), *Beer Continent*, which shows two very characteristic markings, viz. the *Kaiser Sea*, or *Syrtis Major*, and *Dawes' Forked Bay*. The latter was of considerable practical importance in the experiments, as the clearness and fidelity with which it was rendered formed a very useful index of the observer's powers of sight and delineation.

Experiment 1.—A diagram, 5·3 inches in diameter, founded upon a drawing made by M. Antoniadi on 1901 February and published in *Knowledge* for 1902 April. The bulk of the disc was left smooth white; the *Syrtis Major* and *Sinus Sabæus* were

in dead black, *Deucalionis Regio* in grey. Six small dots were put in in dead black roughly in the places of the following "lakes" or "onses":—

Coloe Palus	*Arethusa Lacus*
Copais Lacus	*Siloe Fons*
Ismenius Lacus	*Niliacus Lacus*

The diagram was of the most definite and hard character possible, and there is nothing in it which in the least suggests a "canal" when it is examined close at hand.

The twenty boys were stationed as follows:—

Row.	No. of boys.	Distance. Feet.	Diameter of disc.
a	2	25	61′
b	6	29	52
c	6	35½	43
d	6	41	37

The column "Diameter of disc" gives the angle in minutes of arc subtended by the diagram as viewed from the different benches.

The boys in rows *a*, *b*, and *d* made no indications of "canals": but of those in row *c*, five showed canals corresponding in position with the following members of the Martian "canal" system:—

Argæus	...	...	...	5 observers
Arnon	...	...	...	5 ,,
Deuteronilus	...	...	...	2 ,,
Kison	...	...	...	4 ,,
Pierius	...	...	...	1 ,,
Protonilus	...	...	...	3 ,,
Pyramus	...	...	...	5 ,,

To put the matter in other words, these five boys joined up some of the black dots by straight fine lines, prolonging, in some cases, these lines till they reached the limb or the black oval drawn round the north polar cap.

With regard to the perceptive ability of the boys, all, except one at the smallest distance, represented *Dawes' Forked Bay* as a double inlet; the angular distance between the points of the fork as viewed from the several benches, being

$$a\ 230'' ;\ b\ 200'' ;\ c\ 160'' ;\ d\ 140''$$

One boy showed all the six dots, the smallest having to him

a diameter of 36″. For the other boys the smallest dots recorded were of the following diameters :—

″		″	
34	2 observers.	50	2 observers.
42	3 „	54	2 „
46	3 „	60	3 „
48	2 „	70	2 „

The largest dots missed were

″		″	
25	1 observer.	42	6 observers.
29	2 observers.	46	2 „
34	2 „	48	4 „
36	2 „		

The foregoing table is of some importance, for it shows that an isolated dot, even when dead black on a white ground, would not be perceived if of smaller diameter than about 34″, and would be generally missed if under 40″, whilst such a dot could hardly escape notice if above 50″. This conclusion was so precisely that reached in numerous later experiments that it would be a mere repetition to give the actual numbers obtained in them as well as the foregoing.

Experiment 2.—A hard black-and-white diagram like diagram No. 1, the outlines being copied from a drawing made by Professor Schiaparelli 1890 May 16 (*La Planète Mars*, p. 474). Twenty boys arranged in the same manner and at the same distances as in Experiment 1 took part. The boys were an entirely different set, and the diagram was only 3·1 inches in diameter, its angular diameter being—

$$a\ 35\tfrac{1}{2}'\ ;\ b\ 31'\ ;\ c\ 25'\ ;\ d\ 22'$$

Thus though the distances were the same as in the former experiment the angular diameter of the markings was much diminished. The distance between the points of the fork of *Dawes' Bay* was—

$$a\ 82''\ ;\ b\ 71''\ ;\ c\ 58''\ ;\ d\ 50''$$

This distance was much too small to allow of separating definition, and the *Bay* was therefore always seen as a single marking, or not shown at all. Only one dot was inserted. This was placed roughly in the position of *Arethusa Lacus*. Its diameter was—

$$a\ 41''\ ;\ b\ 36''\ ;\ c\ 29''\ ;\ d\ 25''$$

None of the boys represented it. No "canals," properly so

called, were drawn; but of the six boys in set *d*, at the greatest distance, one drew a fine line from the *Nilosyrtis* to *Margaritifer Sinus*; but this was a segment of a circle and concentric with the edge of the disc, whilst three others drew a straight broad streak corresponding roughly to the northern portion of the *Hiddekel*.

Experiment 3.—As before, a hard black-and-white diagram was prepared, founded in this case upon a drawing made by Professor Schiaparelli 1890 June 9 (*La Planète Mars*, p. 475). A large number of black dots of very different diameters were inserted irregularly in the diagram. The diameter of the disc was 5·95 inches. Twenty boys drew the diagram, and were stationed thus:—

Row.	No. of boys.	Distance. Feet.	Diameter of disc. ′
a	4	38½	44
b	4	43½	39
c	4	49½	34
d	4	55½	31
e	4	61½	28

Two boys, both in row *a*, drew "canals" to the number of seven or eight each. These consisted in every case of fine lines, straight or nearly straight, joining up two or more black dots, and prolonged to the nearest "sea."

Experiment 4.—The same twenty boys as in Experiment 3 were set to draw a black-and-white diagram based on a drawing made by Professor Schiaparelli 1888 May 8–10 (*La Planète Mars*, p. 423). In this diagram a large part of the disc was lightly stippled in with minute dots, far too small to be perceived even at the closest position adopted, but leaving *Elysium* bare, so that that region appeared a little brighter than its surroundings, as it actually does on the planet *Mars* itself.

The distances and the diameter of the disc were the same as in Experiment 3, but the individual boys were made to change their seats.

Five boys showed canals: two in row *a* and three in row *c*. Of the latter, two were the boys who had seen "canals" in row *a* in Experiment 3. Later experiments showed that boys who once began to see "canals" at a favourable distance were more ready to see them afterwards at unfavourable distances. These two boys inclosed *Elysium* in a rectangle of "canals" besides inserting "canals" in many other parts of the disc.

This experiment concluded those made with diagrams of dead black-and-white. Those that follow were all made with pencil-drawings on buff drawing-paper, so that the markings on them were not quite so far removed from the subdued character shown by those on the actual planet itself.

Experiment 5.—Drawing 6·1 inches in diameter based upon one by Professor Schiaparelli made 1888 June 13, and appearing in Tav. V. fig. xiv. of this sixth memoir on the planet. *Elysium* occupied the centre of the disc. Eighteen boys stationed as under took part in the observation :—

Row.	No. of boys.	Distance. Feet.	Diameter of disc. ′
a	3	17	103
b	4	21½	81
c	4	26	67
d	4	30½	57
e	3	35	50

Nine dots were inserted in the diagram, and two boys, one in row *b*, the other in row *c*, represented four of these dots by a slightly broken streak.

Experiment 6.—Drawing 6·05 inches in diameter based upon the diagram on p. 102 of Lowell's *Mars*. In this experiment the oases shown by Mr. Lowell were reproduced approximately as given by him, and three short canals were faintly indicated. Twenty boys observed, and every one without exception showed canals in addition to those really on the disc. These canals were made by joining up the oases by straight lines or by segments of circles, although in a number of cases the oases themselves were not represented. The canals were generally prolonged till they met the limb, or one of the great *Maria*. The boys were seated at the same distances as in Experiment 5, four boys in each row.

Experiment 7.—Drawing 5·8 inches in diameter based upon a drawing made by Professor Schiaparelli on 1888 May 27, and appearing in Tav. IV. fig. vii. of his sixth memoir on the planet, and showing *Dawes' Forked Bay*, the *Margaritifer Sinus*, and the *Mare Acidalium*. Nineteen boys at the same distances as in Experiments 5 and 6. No canals were drawn by them. This experiment, together with Experiments 1 and 2, was prepared with special reference to Mr. Lane's suggestion.

Experiments 8 and 9.—Drawing 6·25 inches based upon one by Professor Schiaparelli made 1890 May 16 (*La Planète Mars*, p. 474). In this experiment none of the canals shown by Professor Schiaparelli were inserted, but a number of small irregular markings were inserted at haphazard. River-like marks were drawn flowing into *Dawes' Forked Bay* and the smaller marking of the same character which Schiaparelli has represented some 30° from it at the mouth of the *Phison*. The region of *Meroe Island* was put in in half-tone.

The same diagram was used in both experiments, nineteen boys taking part in Experiment 8 and twenty in Experiment 9. Combining the two sets in one, the stations were as follows :—

Row.	No. of boys.	Distance. Feet.	Diameter of disc.
a	2	17	105
b	3	19	94
c	4	22½	80
d	3	24	75
e	8	28½	63
f	4	32½	55
g	4	34½	52
h	11	37½	48

The results from these experiments were very full and instructive. In row *a* the boys appeared to be just about the distance when the minute markings on the original were beginning to take the canal-like form. In row *b* one boy saw the markings in their true aspect, to another they appeared as canals, and the third saw them imperfectly as canals. Rows *c* and *d* in every instance showed some canals, some boys seeing several. In row *e* the canals are not quite so well represented, though every boy showed something of them. Row *f* showed very few canals, row *g* a fair number, whilst the great majority in row *h* showed no canals or anything like them.

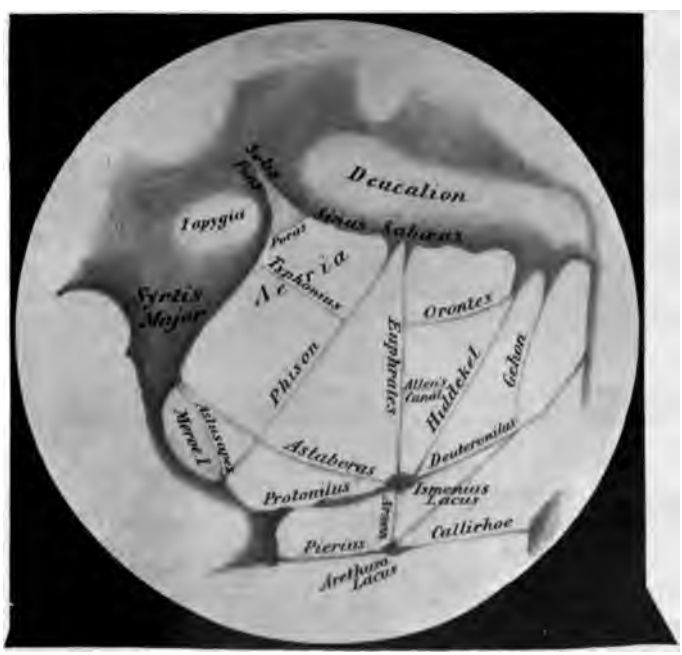
The drawings of the boys in rows *a* and *b* were especially instructive as showing that the actual details, the winding, river-like marks and the miscellaneous dots were to them just visible as such, or were just beginning to be fused into canal-like streaks.

In all twelve canals shown in the recognised charts of *Mars* were more or less faithfully indicated. Some of these were only shown by a single observer, but the six following were frequently represented:—

	a ft.	*b* ft.	*c* ft.	*d* ft.	*e* ft.	*f* ft.	*g* ft.	*h* ft.
Distance	17	19	22½	24	28½	32½	34½	37½
No. of observers	2	3	4	3	8	4	4	11
Phison	2	2	4	2	5	0	2	2
Euphrates	2	2	4	3	6	0	4	3
Hiddekel	2	2	2	2		0	2	2
Gehon	2	1	0	0	1	0	1	2
Arnon	1	1	4	1	3	2	2	4
Deuteronilus	1	1	2	0	1	0	2	0
"Allen's Canal"	1	0	2	0	0	0	0	0

Three boys, one in row *a* and two in row *c*, agreed very closely in inserting a short canal which does not appear to be in Schiaparelli's maps, and which we have here called from the name of its discoverer, "Allen's Canal." A very striking feature is shown in the drawing of this boy Allen in that he prolongs *Aeria* into

ıotograph of the Original Drawing submitted to the Boys in Experiments 8, 9, 10, and 1 Diameter of the original, 6·25 inches.



KEY MAP.

Fig. 1, 17 feet.

Fig. 2, 22½ feet.

Fig. 3, 25½ feet.

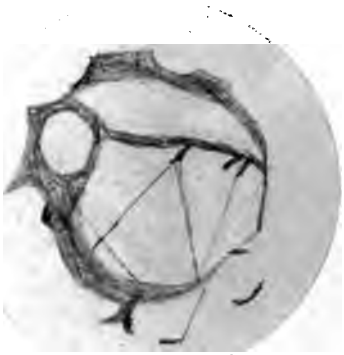


Fig. 4, 28½ feet.

Fig. 5, 34½ feet.

Fig. 6, 37½ feet.

Photographs of the Actual Drawings made by Boys placed at the indicated distance from the original drawing.

the horn-like promontory *Solis Pons*, and cuts it off at its base by the little canal *Porus*, precisely as shown in M. Antoniadi's chart of *Mars* (*Knowledge*, 1902 November, p. 252). There was absolutely no justification in the diagram which he was copying for this marking, but clearly the presence of the two half-tone districts *Iapygia* and *Deucalion* tended to produce the impression that the narrow dark marking between them was partially split by a bright horn. Several other boys showed *Aeria* drawn out into a pointed horn, but not to the same extent that Allen did.

An important feature of this series of drawings was that eleven boys instead of drawing *Meroe Island* as a half-tone district drew the canal *Astusapes*. Only three showed *Meroe Island* distinctly as a half-tone district, and one of the three added a straight line, the canal *Astusapes* as its boundary. The entire marking, however, was not sufficiently distinctive to be clearly recognised by the more distant boys. Only one boy in row *g*, one in *h*, and none in *f* recognised the canal *Astusapes*; and none on these three rows showed any indication of *Meroe Island* as a shaded region. Of the nearer boys, therefore, 50 per cent. showed the canal *Astusapes*, and only 15 per cent. the shaded region.

The following table may prove of interest as indicating the degree of sharpness of sight possessed by the boys in their power to resolve *Dawes' Forked Bay* and the smaller fork at the mouth of the *Phison*.

Row.	No. of boys.	Dawes' Forked Bay. Angles.	Dawes' Forked Bay. Resolved by	Fork of Phison. Angles.	Fork of Phison. Resolved by
		"		"	
a	2	323	1	202	1
b	3	289	3	181	3
c	4	244	3	153	2
d	3	229	3	144	1
e	8	193	7	121	2
f	4	169	3	106	1
g	4	159	3	100	0
h	11	147	11	92	0

The table shows that the resolution was almost always effected down to 150″, the few failures being probably due merely to carelessness or inattention. Below 140″ the falling off is very marked, and none resolve the fork of the *Phison* under 105″. This result is in entire agreement with Experiments 1 and 2, and shows that whilst a single dot is generally seen down to 40″, and even a little below, the resolution of two neighbouring spurs requires a separation about three times as great.

Experiments 10 and 11 were made upon the same drawing, some of the boys in Experiment 8 being moved to new places in Experiment 10. Similarly some of the boys in Experiment 9 were moved to new places in Experiment 11.

In the two experiments taken together, twenty-three boys observed. Of these sixteen were brought forward, seven were moved further back. The results for the boys who were brought forward were of the same general character as in Experiments 8 and 9. Two boys were stationed at only 15 feet from the drawing to be copied. These and those at 17 feet were too near to confuse any details. The boys placed at middle distance perceived canals a little more readily than had been done by their comrades in the same position.

Combining these sixteen boys with the thirty-nine boys who had observed the same diagram before, and grouping together observers at distances which differed only by a few inches, the number of "canals" represented was as follows :—

Distance. Feet.	No. of boys.	Canals drawn.	Canals per observer.
15	2	4	2·00
17	8	26	3·25
19	5	16	3·20
23	9	36	4·00
$25\frac{1}{2}$	3	15	5·00
$28\frac{1}{2}$	8	21	2·63
$33\frac{1}{2}$	9	15	1·67
$37\frac{1}{2}$	11	14	1·27

The seven boys who were moved back to row *h* from rows *b* and *c*, either from memory or from the practice they had already obtained, were much more successful in seeing canals than the boys who had formerly been in this position. It would appear to be not wholly a matter of memory, for one of the seven drew an additional canal beside those which he had seen at the smaller distance. As a rule nothing like "doubling" of the canals was perceived by any of the observers. There were, however, two exceptions, and both related to the same canal, *Hiddekel*. This was clearly doubled in Experiment 9 by a boy at $37\frac{1}{2}$ feet, and in Experiment 10 by another at $25\frac{1}{2}$ feet.

Experiment 12 was upon the same original drawing as that used in Experiment 6; but whereas on that occasion Mr. Lowell's drawing had been reproduced with the oases, but with no canals, now the canals were shown but not the oases, the object being to see whether the boys would insert dots at the juncture of the canals to resemble the oases of Mr. Lowell's original drawing, and also to see whether they would detect actual canals when presented to them. With one single exception all the boys (eleven in number) showed the canals very strongly and unhesitatingly. They had not the slightest difficulty in seeing them. They were seated at $22\frac{1}{2}$ feet (four boys), $28\frac{1}{2}$ feet (four boys), and $37\frac{1}{2}$ feet (three boys). The only boy who did not represent the canals was one at the middle distance, who

showed instead a general shading over the whole district covered by the canals. As a rule oases were not shown, the exceptions being one boy at 28½ feet and two at 37½ feet. The first-named of these three was tried a second time on the back row, and showed more canals than he had done in the nearer position, beside introducing three or four more oases.

Experiment 13.—The same drawing was used as in Experiment 12, with the exception that the canals were not shown but short wavy lines were drawn, radiating irregularly from the position occupied by Mr. Lowell's oases. Ten boys observed, stationed as follows :—

Row.	No. of boys.	Distance in feet.	Diam. of disc.
a	1	15	115
b	1	19	90
c	1	24	71
d	2	28½	60
e	2	32½	53
f	3	37½	46

The boy in row *a* showed a number of canals, but was near enough to the original to see that the markings were not straight. The boy in row *b* put in two canals and some blurred markings. The boy in row *c* developed a fine canal system, showing some eighteen canals in all. The two boys in row *d* showed seven and eight canals respectively. The two boys in row *e* showed a great number of canals, one drawing being specially interesting, as it was a very fairly accurate representation of Mr. Lowell's entire system both of canals and of oases. The boys in row *f* showed little beyond a long elliptical canal, only corresponding roughly with Lowell's system.

Thus in Experiments 6, 12, and 13 the same drawing of the planet was submitted to the boys, but with the following differences :—

Experiment 6.—Oases inserted, but no canals.

Experiment 12.—Canals inserted, but no oases.

Experiment 13.—Neither canals nor oases inserted, but instead short wavy lines.

In each case many canals were drawn by the boys and some oases.

It appears to us in reviewing the entire series of the experiments that it is impossible to escape the conclusion that markings having all the characteristics of the canals of *Mars* can be seen by perfectly unbiassed and keen-sighted observers upon objects where no marking of such a character actually exists. They are in a sense truly "seen," not imagined, because they are the natural rendering by the eye of real markings of a different character.

There are several ways in which this impression of canal-like markings is caused. First, Mr. Green's suggestion that the canals are boundaries of regions of differing shade or tone receives some support. Such boundaries are capable of giving rise to the impression of canals.

Next, so far as the experiments go, the most fruitful source of the canal-like impression is the tendency to join together minute dot-like markings. If these are fairly near to each other it is not necessary, in order to produce the canal effect, that they should be individually large enough to be seen.

But it is not necessary that the markings should be dot-like, that is to say, approximately circular. They may be of any conceivable forms provided only that they are outside the limit of distinct vision and are sufficiently sparsely scattered. In this case the eye inevitably sums up the details which it cannot resolve into fine lines essentially "canal-like" in character. A slight aggregation may give the impression of a spot, or, to use the nomenclature now adopted for the planet *Mars*, an "oasis"; or, if the aggregation be greater still and more extended, to the idea of a shaded area.

So far as these experiments go they do not confirm, as such, the experiments made by Mr. B. W. Lane, or the conclusions which he reached. It was not found that the outlines of the continents of *Mars* were sufficient by themselves to give rise to the impression of the canal system. It is of course a question whether a little training and practice might not have led the boys to recognise canals upon continents which were entirely bare of all internal markings; but we were especially careful not to give the boys the slightest hint that we expected them to see straight lines or dots or anything of the kind. They were told repeatedly to draw all that they could see, but nothing of which they were not certain. And, as a matter of fact, in all these experiments whenever a boy drew a canal there was something on the original which had given rise to that impression, however unlike a canal that something might be.

It will be seen from the figures given above in the body of the paper that the distances at which the boys were stationed ranged in many of the experiments from one whereat the minutest markings were within the range of distinct vision to one so great that to most of the observers these minute markings produced no effect at all; generally speaking, the canals were best seen a little outside the limit of distinct vision.

The result of repeating the experiment with the same boys showed that practice tended to increase the readiness to perceive canals, so that in a second sketch a boy though removed to a greater distance still saw as many canals as at first, in some cases even more.

Generally speaking, the best draughtsmen, that is to say, those who most truthfully represented the salient features of the drawing, also showed the greatest numbers of canals. It is also

worth note that on the whole the agreement as to the canals was greater than the agreement as to the broad features of the original drawing.

We consider Experiment 12 an exceedingly important one, particularly when taken in connection with certain experiments upon the limits of vision not here described. Objects near the limit of vision necessarily divide themselves into two great classes—dots and lines. Now the limit of vision for a straight line is such that if it be of reasonable length its breadth may be $\frac{1}{15}$ of the diameter of the smallest perceptible dot, and it will still be seen. It follows, therefore, that if the surface of *Mars* were really covered with a series of straight lines, like those represented in the charts which we owe to Professor Schiaparelli and Mr. Lowell, there could be no doubt, no controversy, about their existence. Every observer would see them. A straight line can be seen when its angular breadth is very far indeed below the limit of vision for any other form. Consequently when a drawing of *Mars* upon which actual canals were drawn was submitted to the boys they were practically unanimous in showing them with unhesitating distinctness and certainty.

Our conclusion from the entire experiment is that the canals of *Mars* may in some cases be, as Mr. Green suggested, the boundaries of tones or shadings, but that in the majority of cases they are simply the integration by the eye of minute details too small to be separately and distinctly defined. It would not therefore be in the least correct to say that the numerous observers who have drawn canals on *Mars* during the last twenty-five years have drawn what they did not see. On the contrary they have drawn, and drawn truthfully, that which they saw; yet, for all that, the canals which they have drawn have no more objective existence than those which our Greenwich boys imagined they saw on the drawings submitted to them.

It seems a thousand pities that all those magnificent theories of human habitation, canal construction, planetary crystallisation, and the like are based upon lines which our experiments compel us to declare non-existent; but with the planet *Mars* still left, and the imagination unimpaired, there remains hope that a new theory no less attractive may yet be developed, and on a basis more solid than "mere seeming."

Recent Observations of Mars and Jupiter. By W. F. Denning.

On 1903 May 19 and 21 telescopic definition was very good, and a considerable amount of detail visible on *Mars*, especially on the latter night. The *Syrtis Major* appeared abnormally dark and sharply outlined on both dates, while on May 21 a very

bright region crossed its southern extremity (separating it from the seas yet further south), and similarly bright areas lay over *Libya* to the west and north of *Sinus Sabæus* on the east. The best view ever obtained here of *Mars* was on the latter occasion when the configuration* was somewhat as follows.

May 21. 9^h. Long. 281°·8.

On May 23 the planet was observed again at $8^h\ 30^m$, $9^h\ 15^m$, and $10^h\ 30^m$, when, however, definition was not very satisfactory. The *Syrtis Major* exhibited a faintness and indefiniteness of outline which was immediately evident, and which quite astonished me after the experience of previous evenings. This marking, usually the most conspicuous object in *Mars*, had become extremely feeble, as if covered with highly reflective vapours which, though not sufficiently dense to wholly obliterate the object, had suffused it with a much lighter tone. In the early part of the evening the veiled aspect it presented might be accounted for, it being some distance from the centre and near the terminator; but at $10^h\ 30^m$ it had become nearly central, and was most difficult to trace even then. Bad definition could not have induced this effect, for a number of surrounding features,

* The extreme delicacy of some of the features cannot be properly represented in a drawing of this nature, nor is it possible to include all the detail glimpsed at the best moments.

normally less conspicuous than the *Syrtis Major*, were observed; and among these may be mentioned *Syrtis Minor*, *Amenthes*, *Boreosyrtis*, *Nilosyrtis*, *Coloe Palus*, &c. On the following night, May 24, between 9^h and 10^h 30^m the *Syrtis Major* remained feeble and indeterminate, though perhaps not in the same degree as on May 23. Definition, however, was unsteady, but certain other markings were fairly well seen during short intervals, when the seeing was good.

On subsequent nights the *Syrtis Major* came on too late to be suitably observed and a prevalence of easterly winds continued to impair definition. Several times, however—notably on May 25 and 27—a strikingly luminous zone was remarked north of the *Cimmerium Mare*. In fact, during the whole of the last half of May the brilliancy of an extensive belt ranging along the northern borders of *Cimmerium Mare*, *Syrtis Minor*, and *Sinus Sabæus*, was very strongly pronounced.

It seems possible that the bright material which on May 21 appeared to have collected over the equator and on the south side of the *Syrtis Major* may have drifted rapidly northwards and occasioned the faintness of that marking on May 23 and 24.

As affording a possible corroboration of the phenomenon alluded to, the *New York Herald* of May 31 contained a telegram from the Flagstaff Observatory mentioning that a projection had been seen on *Mars* on May 26 in latitude 22° north and longitude 37° west. "Professor Lowell says it must have been an enormous cloud travelling northwards and dissipating as it went. This deduction is proved by its non-appearance next day."

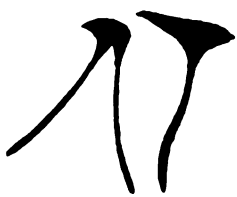
I had previously noticed on May 4 a probable instance of change in another region of *Mars*. The canal *Nilus*, running east from *Lunæ Lacus*, exhibited a very well-marked division. There was a bright, glowing spot attached to the east side of the very dark *Mare Acidalium*, and a stream of luminous material apparently flowed from this centre far to S.E., crossing *Nilus* and cutting through the dusky material forming the canal. On the following night the same aspect was repeated, but less decidedly. The division in *Nilus* had not been seen by me on March 31 or April 2, when the conditions were very good and the diameter of *Mars* (14″·6) greater than on May 4 (12″·7). Nor was this feature noticed in 1886 March and April, when I made several drawings of the same region.

A bright spot in *Elysium*, immediately on E. side of *Trivium Charontis*, was on many occasions observed as a striking pearl-like object when on or very near the edge of the disc; but when far inside the border or near central region the contrast was not nearly so strong. The intensification of the bright spots when on the margin of the disc has sometimes probably occasioned their recognition as "projections." The appearance alluded to is by no means a new feature. The bright spot described above as situated east of the *Mare Acidalium* was frequently seen by

Mr. E. B. Knobel in 1873 May, and its position indicated in a number of sketches (*Monthly Notices*, vol. xxxiii. p. 476). Mr. Knobel says: "I thought the spot brighter on the terminator than when near the centre of the disc. The sketch made May 22 represents the white spot apparently raised above the disc by irradiation." Mr. N. E. Green also says: "One of the most marked features of the opposition of *Mars* now past has been the frequent appearance of masses of light on the limb which never arrived at the meridian" (*Monthly Notices*, vol. xlvi. p. 447, 1886 June).

With regard to the question of real or supposed changes in Martian detail we must obviously be prepared to make large allowances for variations in the character of the seeing, and it should be remembered that the observer himself is liable to certain perturbations which may materially affect his results. But while fully considering such influences I believe that very palpable alterations occur in the aspect of some of the features, though such variations are only temporary and due to atmospheric causes.

Some writers (including the Rev. E. Ledger, who has a paper on the subject in the *Nineteenth Century* for May) apparently regard the objective existence of the canals as still open to question, but there is really no doubt whatever about the streaked or striated configuration of the northern hemisphere of *Mars*. The canals do not appear as narrow straight deep lines in my telescope, but as soft streams of dusky material with frequent condensations. This statement holds good as regards the usual appearance of the more delicate features. But on a few occasions the canals, where they join the seas just south of the equator and cross the bright areas to be found there, were outlined very sharply. For instance on May 9 and 12 the canals running north from the region of the "Forked Bay" appeared under this aspect:—



The double canals are an optical effect only, though in a few cases two canals may lie near together and run almost parallel; their contiguous situation appears, however, to be the result of accident. The surface lineaments generally are as plentiful as they are irregular and unsymmetrical, and their aspect is far more highly suggestive of natural than artificial production.

Jupiter was observed on the mornings of May 27, June 1, 4, 5, 6, and 7. A few selected transits were as follows:—

		h m	Long. °	System.
Great Red Spot	May 26	16 18	29·5	II.
„ „	May 31	15 28	30·4	„
„ „	June 5	14 33	28·3	„
P. end dark mass, S. tropical zone	June 6	15 16	204·5	„
Very bright equa. spots	June 3	15 19	268·1	I.
	June 6	14 49	3·4	„
Very dark equa. spot	June 3	15 0	256·5	„
Dark N. tropical spots	June 3	14 45	95·1	II.
	June 3	15 28	121·0	„
	June 3	16 1	141·0	„
Dark N. temp. spot	May 26	15 38	5·3	„
	May 31	14 50	7·4	„
Dark N.N. temp. spot	June 6	15 12	202·1	„

The accelerated motion of the Great Red Spot has been continued for this object, has lost about 8° in longitude since 1902 December (when it was 37°), and this corresponds to a rotation period of $9^h\ 55^m\ 38^s{\cdot}8$. The large dark spot in the S. tropical zone, frequently observed in 1901 and 1902, is still prominently visible, and its p. side will be in longitude 185° at the middle of 1903 July.

In the various observations here described a 10-inch reflector was employed with a power of 312, but occasionally on *Mars* magnifiers up to 488 were found serviceable.

Bishopston, Bristol: 1903 *June* 7.

Postscript.—From my subsequent observations of the Great Red Spot on *Jupiter*, including one obtained on July 13, $16^h\ 2^m$, when the object was in longitude 32°·8, it appears certain either that the motion has been recently retarded or that my transits at the end of May and beginning of June were a little too early.

July 14.

Observations of the Satellite of Neptune from Photographs taken at the Royal Observatory, Greenwich, between 1902 *November* 12 *and* 1903 *April* 27.

(*Communicated by the Astronomer Royal.*)

The following measures of position-angle and distance of *Neptune's* satellite were made from photographs taken with the 26-inch refractor of the Thompson Equatorial. The occulting shutter was used when not otherwise noted, and the position of

the plate adjusted so that the planet was behind the shutter while the satellite was just outside it. In one or two cases the planet was not put sufficiently far behind the shutter so that the image falls very near its edge and is not clearly separated from the outer halo. These are noted as "partly occulted."

By an arrangement of Mr. Davidson's the occulting shutter has been made to work automatically, so as to give an exposure of about $\frac{1}{10}$^{s} every 20^{s} to the planet, the satellite being meanwhile exposed for from 20^{m} to 30^{m}.

The zero of position-angle was obtained by stopping the clock and giving a short supplementary exposure. Generally, several short exposures were given, the clock being stopped for a short time between each of them.

Owing to wind on some nights and bad definition on others, this series of photographs is not quite so good as that taken between 1902 January 6 and 1902 April 10.

The photographs were taken by Messrs. Davidson, Edney, or Melotte, and the measurement of the photographs was made by Mr. Edney and Mr. Burkett, in the manner described in *Monthly Notices*, vol. lxii. p. 623. A mean correction for refraction has been applied.

The tabular positions were computed from the data given in the *Connaissance des Temps* based on Dr. H. Struve's elements, the eccentricity of the orbit being neglected owing to the uncertainty as to the present position of the periastron.

Neptune and Satellite.

Position-angle and Distance, from Photographs taken with the 26-inch Refractor.

Date and G.M.T.				Position Angle.			Distance.			Remarks.
1902.	d.	h.	m.	s.	Observed.	Tabular.	T-O.	Observed.	Tabular.	T-O.	
					°	°	°	″	″	″	
Nov.	12	11	44	44	60·40	59·51	−0·89	15·04	14·85	−·19	Not occulted.
	12	12	21	2	58·56	58·21	−0·35	14·19	14·71	+·52	Not occulted.
	12	13	34	26	55·57	55·53	−0·04	14·45	14·41	−·04	Not occulted.
	12	14	8	35	55·34	54·24	−1·10	14·14	14·26	+·12	Not occulted.
	13	11	37	32	345·61	342·98	−2·63	10·89	11·03	+·14	
	13	12	3	44	340·65	341·31	+0·66	10·85	11·08	+·23	
	17	11	34	29	95·16	96·87	+1·71	16·71	16·40	−·31	
	20	11	32	53	274·09	274·35	+0·26	—	—		Planet partly occulted.
	20	12	14	44	272·24	273·16	+0·92	—	—		Planet partly occulted.
	28	12	2	51	135·78	136·10	+0·32	12·70	12·48	−·22	
	28	12	35	27	135·21	134·48	−0·73	12·70	12·62	−·08	Satellite faint.
Dec.	29	7	41	34	68·66	67·83	−0·83	15·78	16·03	+·25	Satellite very faint.
	29	8	17	4	66·84	66·73	−0·11	15·60	15·92	+·32	Satellite faint.

Date and G.M.T.				Position Angle.			Distance.			Remarks.
				Observed.	Tabular.	T-O.	Observed.	Tabular.	T-O.	
d.	h.	m.	s.	°	°	°	″	″	″	
31	10	17	26	281·42	281·98	+0·56	15·73	15·94	+·21	
31	10	53	20	280·98	280·88	−0·10	15·88	16·05	+·17	
1	12	49	30	234·64	234·52	−0·12	14·57	14·59	+·02	
3	9	14	8	98·43	101·18	+2·75	15·68	16·01	+·33	Very faint.
3	9	47	52	98·28	100·15	+1·87	16·04	16·10	+·06	
15	9	40	9	89·37	91·54	+2·17	17·21	16·75	−·46	
15	10	13	32	89·09	89·05	−0·04	16·64	16·79	+·15	
15	10	55	44	87·16	87·88	+0·72	16·52	16·82	+·30	
23	9	3	23	311·49	313·17	+1·68	12·67	12·52	−·15	
23	9	32	6	309·83	311·76	+1·93	12·59	12·64	+·05	
23	10	4	28	307·03	310·19	+3·16	12·67	12·78	+·11	Planet partly occulted.
25	9	1	42	215·28	214·01	−1·27	12·69	12·50	−·19	Satellite faint.
28	7	40	55	33·63	33·64	+0·01	12·20	12·47	+·27	
28	8	13	12	29·36	32·01	+2·65	11·84	12·33	+·49	
1	9	40	25	116·37	119·57	+3·20	13·90	13·77	−·13	Satellite very faint.
2	8	5	51	77·00	77·77	+0·77	16·67	16·68	+·01	
6	9	4	8	191·21	194·33	+3·12	11·36	11·25	−·11	Satellite very faint.
10	8	45	32	290·70	291·47	+0·77	15·26	14·59	−·67	Satellite very faint.
10	9	22	25	289·89	290·15	+0·26	15·23	14·74	−·49	
16	11	29	9	278·93	280·16	+1·23	15·57	15·76	+·19	
16	11	54	33	279·26	279·38	+0·12	15·56	15·83	+·27	
17	7	32	13	246·67	245·83	−0·84	15·48	15·73	+·25	Satellite very faint.
17	8	2	41	244·06	244·89	+0·83	15·61	15·64	+·03	Satellite very faint.
17	8	53	7	243·87	243·30	−0·57	15·17	15·48	+·31	
18	9	45	50	167·75	169·00	+1·25	10·95	10·76	−·19	
18	10	13	4	166·28	167·21	+0·93	10·71	10·72	+·01	
18	10	39	23	165·23	165·49	+0·26	10·64	10·79	+·15	Satellite ill-defined.
23	7	26	6	239·34	240·37	+1·03	15·15	15·13	−·02	Satellite very faint.
26	8	11	58	54·97	55·80	+0·83	14·43	14·59	+·16	
28	8	45	50	273·88	274·44	+0·56	16·17	16·14	−·03	
28	9	11	41	272·80	273·69	+0·89	15·86	16·19	+·33	
28	9	38	16	271·28	272·93	+1·65	15·65	16·24	+·59	
3	7	20	8	92·28	94·38	+2·10	16·31	16·11	−·20	Satellite very faint.
3	7	59	50	93·97	93·22	−0·75	15·77	16·19	+·42	
3	9	56	42	91·53	89·91	−1·62	16·31	16·38	+·07	Satellite very faint.
6	8	50	4	269·23	269·30	+0·07	16·01	16·38	+·37	
6	9	15	38	267·32	268·59	+1·27	16·14	16·42	+·28	
6	9	43	32	266·89	267·82	+0·93	16·53	16·44	−·09	

Date and G.M.T.				Position Angle. Observed.	Tabular.	T-O.	Distance. Observed.	Tabular.	T-O.	Remarks.
1903.	d.	h.	m. s.	°	°	°	″	″	″	
	11	8	33 45	315·87	316·18	+0·31	11·67	11·94	+·27	
	11	9	7 2	314·72	314·46	−0·26	11·79	12·07	+·28	
	13	8	24 15	216·73	217·26	+0·53	12·35	12·56	+·21	Satellite faint.
	15	8	32 36	81·94	82·48	+0·54	16·33	16·44	+·11	
	15	9	14 32	80·24	81·33	+1·09	16·19	16·44	+·25	
	16	10	19 44	26·92	26·98	+0·06	11·90	11·72	−·18	
	16	10	46 43	25·58	25·51	−0·07	11·73	11·62	−·11	
	21	8	38 54	77·70	77·45	−0·25	15·84	16·28	+·44	
	21	9	7 50	77·16	76·65	−0·51	15·57	16·25	+·68	Satellite faint.
	26	9	19 19	112·97	114·45	+1·48	13·72	13·88	+·16	
Apr.	14	7	59 40	55·34	57·23	+1·89	14·38	14·34	−·04	Planet partly occult
	16	8	17 11	274·31	276·19	+1·88	15·63	15·61	−·02	
	17	8	22 2	233·39	233·24	−0·15	14·03	13·88	−·15	
	24	8	39 47	141·01	141·93	+0·92	11·33	11·32	−·01	
	27	8	39 49	316·08	317·16	+1·08	11·80	11·63	−·17	

The Great Nebula in Auriga. By Dr. Max Wolf.

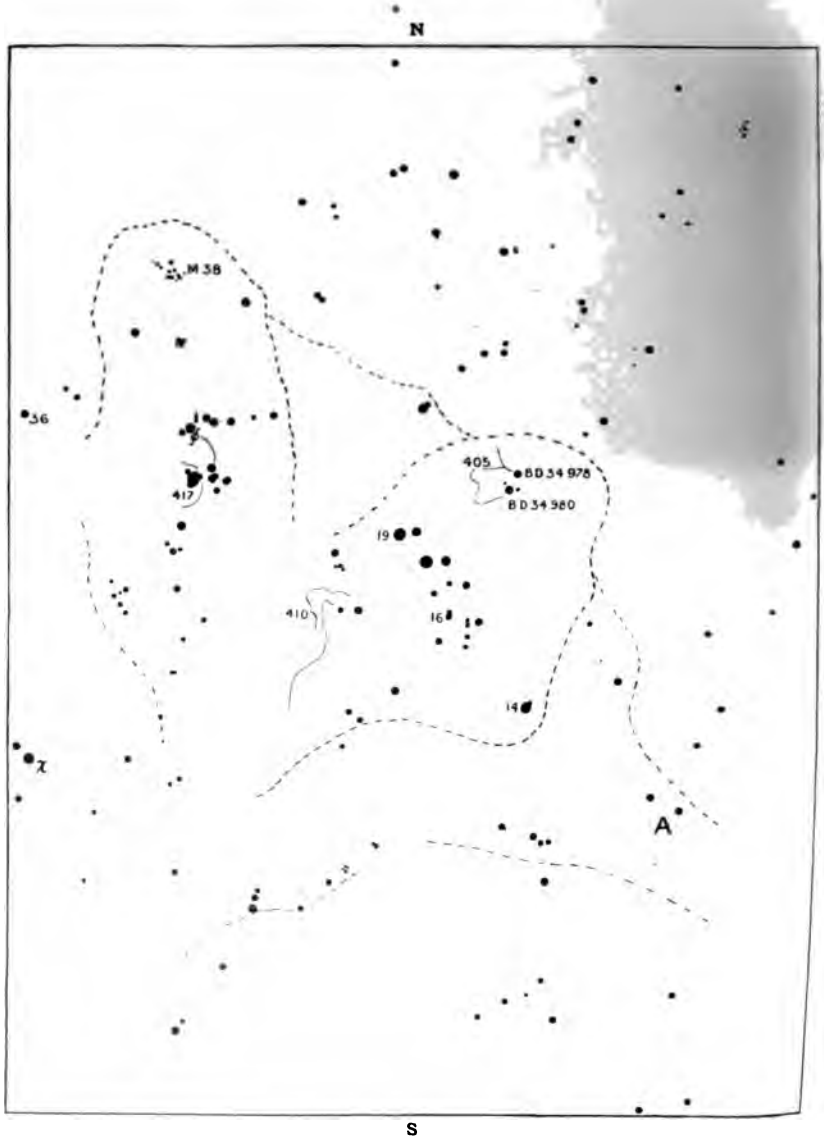
In *Astr. Nachr.* 3130 (1892 October 9) I gave a description of some recently discovered nebulæ in *Auriga*. The most remarkable of these was discovered independently by Schaeberle, E. von Gothard, and myself near the 6·7 mag. star B.D. + 34°, 980. This nebula has received the number 405 in Dreyer's Index Catalogue. Two other nebulæ then discovered were given by Dreyer the numbers 410 and 417; to the east of 417 lies the nebula G.C. 1137.

When photographing the region of Nova *Aurigæ* with the two 16-inch Brashear lenses on the evening of 1902 March 6 with five hours' exposure I found a large diffused nebulosity at the edge of the plates near the places of the above-named nebulæ. In the present year, on 1903 February 19, I took a further photograph with the region in the centre of the field of my two 16-inch lenses.

The plates were exposed from $7^h\ 9^m$ to $12^h\ 14^m$ Koenigstuhl M.T. They show such interesting nebulosities that I send the accompanying pictures to the Society.

The reproduction (plate 20) is an untouched contact print from one of the original plates. A great part of the plate is covered with nebulosity, condensed around five bright groups,

KEY MAP.



NEBULOSITIES IN AURIGA.

NEBULOSITIES IN AURIGA.

PHOTOGRAPH BY DR. MAX WOLF, HEIDELBERG.

which form a great V. It looks like a photograph of the V of *Taurus*, the corner shifted somewhat westward.

The five groups are as shown on the key map (proceeding from east to west); first, the splendid cluster, Messier 38 and its accompanying cluster, Herschel VII. 39; second, the group near ϕ *Aurigæ*; third, the great nebulæ Ind. Cat. 410; then the group with the bright stars near 16 and 19 *Aurigæ*; and finally the remarkable nebula Ind. Cat. 405 connected with the B.D. star 34°, 980. Herschel's G.C. 1137 between Ind. Cat. 417 and the star 36 *Aurigæ* is involved in the same luminous matter.

It was in 1892 (September 25 and 30) that I first photographed the nebulæ Ind. Cat. 417, 410, and 405. My present intention is to show the *connection* between all these nebulæ, star groups, and clusters. It will be seen from the plate and key map that the above-named five or six groups are involved in the same nebulosity. This appears to support the theory that nearly all these stars, clusters, and nebulæ are at the same order of distance from our Earth as in similar cases in *Cygnus* and *Orion*.

The nebulæ G.C. 1137, I.C. 417 and 410 show many interesting features, but are much surpassed by the nebula Ind. Cat. 405. The more distant exterior parts of this nebula are of interest as showing the *lacuna-forming* forces of the nebulæ: the north and north-western borders form the boundaries of a great lacuna in which the fainter stars seem to have disappeared. The same is the case with the western borders of the branch A (see key map). The drift is here always from west or north-west towards east. This matter deserves further investigation by careful counts of the number of stars in the different regions.

I only wish to direct attention to the remarkable inner structure of the nebula I.C. 405. My second photograph, of which I send short and long printed pictures,* is enlarged about five times from the original plate without retouching.

The long printed picture shows the interior parts and the disc of the star; on the shorter printed one the disc of the star flows into the surrounding nebulæ, but the more distant nebulæ are quite visible. The large star-disc is B.D. 34°, 980. It looks like a burning body from which several enormous curved flames seem to break out like gigantic prominences. One of these seems to connect B.D. 34°, 980 with the 7·8-magnitude star B.D. 34°, 978.

It seems to me that it would be interesting to examine this "*flaming star*" with the spectroscope, and I hope that my pictures may draw the attention of spectroscopists to this star, which seems physically connected with the nebulous matter.

Koenigstuhl Astrophysical Observatory:
1903 *June.*

* The detailed structure of the nebula I.C. 405 is, however, better shown in the photograph published by Dr. Isaac Roberts in *Knowledge* for 1903 April. The editors of the *Monthly Notices* have therefore not considered it necessary to reproduce Dr. Wolf's enlarged photographs.

Further Observations of the New Star in Auriga, with the Mean Magnitudes for the years 1892–1903, from estimations made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., D.Sc., F.R.S., Radcliffe Observer.*)

The observations of Nova *Aurigæ* given in this paper are in continuation of those published in the *Monthly Notices*, vol. lxi. p. 543. Estimations of the magnitude of this star have also appeared in vol. lii. pp. 430–1, vol. liii. pp. 33, 34, 126, vol. lv. p. 164, vol. lvi. p. 234, vol. lviii. p. 180, and vol. lix. p. 258.

A further decrease of brightness was noted at the beginning of this year, when the object proved a very difficult one with the 10-inch Barclay telescope.

1902 Dec. 31. $11^h\ 45^m$ G.M.T. Barclay Equatorial, power 90.

Nova fainter than any of the comparison stars in the chart (*Monthly Notices*, vol. lii. p. 431).

Nova = c' near c, or M of Burnham's list (*Monthly Notices*, vol. lii. p. 435). M was estimated on 1900 Nov. 17 in the Barclay 0·2 mag. fainter than p (*Monthly Notices*, vol. lxi. p. 543).

Nova visible in glimpses, and seen best by averted vision (R.).

1903 Jan. 2. 11^h G.M.T. Barclay Equatorial, power 85.

Nova fainter than any of the comparison stars in the chart, but equal to Burnham's M, or c' near c (Radcliffe chart). (R.)

1903 Jan. 2. $11^h\ 10^m$ G.M.T. Power 180.

Nova distinctly seen and equal to Burnham's M, or c', but slightly fainter than p. With this power the star close to the Nova (designated in Burnham's list as B) is just visible, and is very nearly at the limit of vision with the Barclay telescope. The Nova is approximately a magnitude brighter than this star (R.).

The resulting magnitudes of Nova *Aurigæ* are :

	Radcliffe Scale.*	Burnham's Scale.†	Barnard's Scale.‡
1902 Dec. 31	14·5	13·2	12·2
1903 Jan. 2	14·5	13·2	12·2

Observer : R., Mr. Robinson.

* *Monthly Notices*, vol. lii. p. 431.
† *Monthly Notices*, vol. lii. pp. 433–6.
‡ *Monthly Notices*, vol. lxii. p. 65.
Erratum.—*Monthly Notices*, vol. lxi. p. 543, sixth line from bottom: *For* between *read* beyond.

The mean magnitudes from 1892 to 1903 are:

1892	4·5 to <14·0, Feb. 3 to March 31.
1892	9·5 to 9·8, Sept. 8 to end of year.
1893	9·7
1894	9·7
1895	9·7
1896	—
1897	11·4
1898	12·0
1899	13·4
1900	13·9
1901	—
1902–3	14·5

Radcliffe Observatory, Oxford:
1903 *June* 11.

Further Observations of the New Star in Perseus made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

This paper is in continuation of the notes on the same subject published in the *Monthly Notices* for 1901 March, April, May, June, November, and 1902 June.

The Nova is gradually diminishing in brightness, but more slowly than before. During 1902 the rate of diminution was about $0^{M}\cdot004$ or $0^{M}\cdot005$ per diem.

The colour was still bluish on September 3.

The magnitudes of the last five comparison stars in the list are those of Hagen's *Second Chart and Catalogue for Observing Nova Persei.*

TABLE I.

List of Stars used for comparison with Nova Persei.

Ref. No.	Name of Star.	Adopted Tabular Magnitude.	Authority for Magnitude.
77	Arg. Z. +43° 739	9·0	Argelander D.M.
81	Arg. Z. +43, 744	8·6	,, ,,
82	Arg. Z. +43, 746	9·1	,, ,,
83	Arg. Z. +43, 751	9·0	,, ,,
84	Arg. Z. +43, 749	9·0	,, ,,

Ref. No.	Name of Star.	Adopted Tabular Magnitude.	Authority for Magnitude.
85	Arg. Z. +43°. 743	9·4	Hagen (Chart II.).
86	Hagen II. 42	10·1	" "
87	Arg. Z. +43. 738	9·7	" "
88	Arg. Z. +43. 737	9·8	" "
89	Hagen II. 44	10·3	" "

TABLE II.

Means of Estimations of Magnitude of Nova Persei.

1902.	G.M.T. h m	Observer.	Aperture of Telescope. Inch.	Power used.	Reference Stars.	Mean Mag. of Nova Persei.
Sept. 3	13 30	R.	10·0	90	77, 85, 86	9·35
5	11 0	W.	"	"	77, 86	9·50
6	10 45	R.	"	"	81, 82, 83, 84, 77, 85, 87, 88, 80, 89	9·38
Dec. 31	11 20	R.	"	"	77, 85, 86	9·93

Observers' Remarks.

1902.
Sept. 3. The image of the Nova is dull and bluish. The comparison star No. 86 has a very faint companion following (R.).

Observers: W., Mr. Wickham; R., Mr. Robinson.

Radcliffe Observatory, Oxford:
1903 *June* 11.

Observations of the New Star in Gemini made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

On March 25 we received from Professor Turner an announcement of his discovery of a new star in *Gemini*. The first opportunity of observing the object occurred on March 26, and since then observations at intervals have been made of its brightness.

The star has generally presented a red or reddish appearance; but observers' notes seem to suggest the probability that there is a slight change taking place in colour in the direction of diminishing redness.

The observations show a decline in the brightness of the star at an average rate of about $0^{M}\cdot015$ per diem. The diminution is not quite uniform, but the observations are not sufficiently

numerous to enable us to decide whether the variations are real or apparent.

The magnitudes of the comparison stars Nos. 1, 3, and 4 are taken direct from the Harvard Photometric Durchmusterung; those of Nos. 2, 5, 9, and 11 are the Harvard values as given in the "Notes" column of Hagen's *Chart and Catalogue for Observing Nova Geminorum*; while those of the remaining stars of the list are based on Radcliffe estimations on the Harvard scale.

TABLE I.

List of Stars used for comparison with Nova Geminorum.

Ref. No.	Name of Star.	Adopted Tabular Magnitude.	Authority for Magnitude.
1	Arg. Z. +29°, 1342	8·16	Harvard Photom. D.M.
2	Arg. Z. +30, 1320	8·53	Harvard (Hagen's Chart).
3	Arg. Z. +30, 1306	8·76	Harvard Photom. D.M.
4	Arg. Z. +30, 1332	8·01	„ „ „
5	Arg. Z. +30, 1316	9·26	Harvard (Hagen's Chart).
6	Hagen 30	9·66*	Radcliffe observations, based on Harvard.
7	Arg. Z. +30, 1321	9·56	„ „ „ „
8	Arg. Z. +29, 1328	9·56	„ „ „ „
9	Arg. Z. +30, 1309	10·13	Harvard (Hagen's Chart).
10	Arg. Z. +30, 1315	(10·22)	Radcliffe observations, based on Harvard.
11	Arg. Z. +30, 1317	10·08	Harvard (Hagen's Chart).

TABLE II.

Means of Estimations of Magnitude of Nova Geminorum.

1903.	G.M.T. h m	Observer.	Aperture of Telescope. Inch.	Power used.	Reference Stars.	Mean Mag. of Nova Geminorum.
March 26	8 10	A.A.R.	10·0	45	1, 2	8·70
	8 10	W.	„	„	1, 2	8·62
	10 0	R.	„	„	1, 3, 2	8·58
	10 0	C.	„	„	1, 3, 2	8·54
30	12 15	R.	7·5	„	1, 3, 2	8·61
April 4	9 45	R.	10·0	„	4, 1, 3, 2	8·67
13	8 30	R.	„	„	3, 2, 5, 6	9·13
20	11 0	R.	„	„	3, 2, 5, 6	9·13
29	9 30	W.	„	„	—	10· ±
May 4	9 45	R.	„	„	1, 2, 5, 6, 9	9·45
8	9 0	W.	„	„	5, 6	< 9·66
20	10 40	R.	„	„	1, 3, 2, 5, 7, 8, 6, 11, 9, 10	9·42

* No. 6. Wide double. Combined light observed.

Observers' Remarks.

1903.
March 26. Nova is reddish-yellow (W.). Nova distinctly red (R.). Nova reddish (C.).
March 30. Observed with the Heliometer. The magnitude of Nova and comparison stars are sensibly the same as those observed with the Barclay on March 26 (R.).
April 4. Nova reddish, not so red as on March 26, but moonlight strong to-night (R.).
April 13. Nova red (R.).
April 29. Tried to estimate magnitude of Nova, but clouds too frequent. I should think it is as low as 10 mag., but night very unfavourable (W.).
May 4. Sky hazy, moonlight strong (R.).
May 8. Nova fainter than Nos. 5 and 6. I could not see No. 6 as a double, and the smaller stars were obliterated by increasing haze. Sky quite thick at 9.30 G.M.T. (W.)
May 20. Stars very low. Observations of the two faintest stars (Nos. 9 and 10) difficult (R.).
June 3. Nova looked for at 10^h G.M.T., but was not visible. Twilight too strong, and altitude of object small (R.).

The observers were :—

Dr. Rambaut, indicated by		...	...	...	A.A.R.
Mr. Wickham,	,,	...	...	...	**W.**
Mr. Robinson,	,,	...	...	...	R.
Mr. McClellan,	,,	...	...	...	C.

Radcliffe Observatory, Oxford :
1903 *June* 11.

Positions of 166 *Stars around Nova Geminorum; with a Discussion of Systematic Differences between two Exposures on the same Plate.* By F. A. Bellamy.

In a paper (*Monthly Notices*, vol. lxiii. p. 326) I gave the magnitudes and positions of Nova *Geminorum* and fifteen stars near it. The plate from which those results were derived did not show many stars fainter than the 10·3 magnitude. Since that date several plates of the region have been obtained, among them being the two upon which this paper is based :

	Centre.			
Plate 2222,	+ 30°,	6^h 36^m,	exposed 1903 April 17 for	30 min. and 35 min.
,, 2240	,,	,,	,, ,, ,, 22	,, 100 min.

As this portion of the sky was considerably towards the western horizon when darkness commenced the mean hour-angles for these three exposures were 3^h 55^m, 4^h 24^m, and 5^h 2^m respectively.

On plate 2222 125 stars have been measured in a square with sides equal to 30′ surrounding the Nova, which is approximately 80ˢ to the east and 2½′ north of the plate centre; from this number it may be estimated that there are 2,400 stars on the whole plate. On plate 2240, with 100 minutes' exposure, only four réseau squares, equal to a square with sides of 10′, with the Nova in the centre, have been used, and within this area 57 stars have been measured, from which it may be estimated that there are certainly not less than 10,000 stars on the whole plate. On both these nights the sky was clear, but the hour-angles at which the three exposures were made would tend to reduce the number of the faintest stars that would have been recorded if the plate had been exposed on the meridian.

Plate 2222.

This plate covers the region in which the positions of 51 stars have been recorded in the Cambridge and Leiden A.G. Catalogues. These positions were brought up to epoch 1900·0, with precessions (given in the catalogues), but no corrections for proper motion, magnitude equation, or systematic differences between the catalogues have been applied, and the places for 1900·0 were then converted into standard coordinates in réseau intervals as unit for plate centre R.A. $6^h\ 36^m$, Decl. $+30°$. If (ξ, η) denote standard coordinates referred to the plate centre as origin $\xi' = \xi + 13$, $\eta' = \eta + 13$, so that (ξ', η') are referred to the corner of the réseau and are always positive, and (x, y) denote measures on the plate expressed in réseau intervals, each measure being the mean of two in direct and reversed positions of the plate. Then putting

$$ax + by + c = x - \xi$$
$$dx + ey + f = y - \eta$$

the values of a, b, c, d, e, f were separately determined for each exposure as follows:

	a	b	c	d	e	f
Exposure I.	−·00057	−·00003	+·0586	−·00030	−·00068	−·0258
,, II.	−·00066	+·00005	+·0635	−·00049	−·00075	−·1713

The differences in the constants c and f are due to the displacement of the telescope in order to get the two exposures sufficiently separated on the plate; the differences in the other constants are partly due to refraction effects and partly accidental.

The effect of differential refraction (see *Monthly Notices*, vol. liv. p. 18) is to *diminish* the coordinates by the quantities

$$\beta_0(1 + X^2)x + \beta_0 XY y$$
$$\beta_0 XY x + \beta_0(1 + Y^2)y$$

where XY are the coordinates of the zenith on the plate expressed in circular measure and β_0 is the coefficient of refraction. Adopting $\beta_0 = 1/3600 = \cdot000278$, the numerical values of these are

Exposure I. ... (H.A. $3^h\ 55^m$) $+\cdot00045x + \cdot00017y$; $+\cdot00017x + \cdot00044y$
„ II. ... (H.A. $4^h\ 24^m$) $+\cdot00052x + \cdot00023y$; $+\cdot00023x + \cdot00050y$

and if we subtract this effect of refraction the constants given above become

		a'	b'	d'	e'
Exposure I.	...	$-\cdot00012$	$+\cdot00014$	$-\cdot00013$	$-\cdot00024$
„ II.	...	$-\cdot00014$	$+\cdot00028$	$-\cdot00026$	$-\cdot00025$

which are in satisfactory accordance, if we admit a possible change of orientation of ·00014 between the exposures. [It may be remarked that no special care has been recently exercised in adjusting the polar axis, as for short exposures no such care is necessary.]

When the measures of individual stars are corrected by the above formulæ and compared with the calculated standard coordinates residuals are found, as in the following Table I. The agreement between the two exposures is satisfactory generally; in one case only is there a difference of ·005 or 1″·5; in three cases of ·004 or 1″·2; all other differences are less than 1″·0.

It may be remarked that 9·5 magnitude stars give discs about 7″ in diameter with these long exposures; thirty of the fifty-one stars measured have diameters over 12″, and some diameters exceed 20″, and it is not easy to bisect accurately these large images.

TABLE I.

Residuals for the Reference Stars.

No. in Camb. or Leiden.	1st Exp. x.	2nd Exp. x.	1st Exp. y.	2nd Exp. y.	No. in Camb. or Leiden.	1st Exp. x.	2nd Exp. x.	1st Exp. y.	2nd Exp. y.
3365	+002	+003	+001	−002	3443	+004	+006	000	+004
3369	−001	−001	+003	+001	3446	−004	−002	+004	+002
3371	+003	000	+003	+003	L 2782	+005	+002	−002	−003
3374	−006	−007	−003	+001	3447	−010	−010	+003	+001
L 2733	−005	−005	−001	−001	L 2784	+002	+001	−001	+002
L 2735	+005	+002	−001	−004	L 2786	+002	+001	−001	−002
3377	−001	−001	−002	−001	L 2789	−002	−002	+001	+001
L 2737	+004	+005	−004	−005	3455	−004	−003	000	000
3381	−003	000	+002	000	L 2793	+003	+003	−003	−003
L 2742	+002	+002	+003	+003	L 2794	+002	+002	+005	+003
3388	−008	−006	+002	+003	L 2797	+001	−001	+002	−002
3390	−001	+001	+003	+002	3465	+003	+001	−003	000

No. in Camb. or Leiden.	1st Exp. x.	2nd Exp. x.	1st Exp. y.	2nd Exp. y.	No. in Camb. or Leiden.	1st Exp. x.	2nd Exp. x.	1st Exp. y.	2nd Exp. y.
L 2754	+001	−001	−002	−001	3467	−013	−013	000	+001
3400	−002	−001	+006	+003	L 2799	+002	000	000	−002
3404	−002	−004	−001	−004	L 2800	−001	000	+001	−002
3406	−003	−002	+001	+003	3468	−005	−005	−001	−001
3407	+001	+001	+002	+004	3469	+001	000	+002	+004
3409	−009	−008	−010	−005	L 2803	+001	+003	−001	−001
L 2763	+003	+003	−001	−002	3471	−004	−004	−003	−003
3424	−001	−001	−003	−004	3473	+002	+002	000	−001
3425	+003	+003	+002	+001	L 2805	000	−002	−003	−003
3426	+002	+003	000	+002	3477	+003	+004	−001	−001
3430	000	−001	+007	+008	3482	−002	−001	+002	+003
L 2773	+004	+003	000	000	L 2815	−003	−001	000	000
3439	+003	+005	000	−001	3486	−004	−002	−003	−005
3441	+004	+002	−001	+001					

Besides measuring these fifty-one stars I also measured on this plate 125 stars near the Nova. These measures were corrected by the formulæ derived above and the standard coordinates deduced.

Before combining the two exposures the differences between them were formed, and it was found that the mean differences were

$x_I - x_{II}$	$y_I - y_{II}$
+ ·00074 or + 0″·22	− ·00044 or − 0″·13

The mean of the differences without regard to sign is ± ·0013 or ± 0″·4 in both x and y, so that the above means are too large to be entirely accidental. The constants deduced from the Cambridge and Leiden stars do not seem entirely to suit the faint stars near the Nova, and the cause may be sought either in the difference of brightness or in the locality ; and, further, it may be of such a kind as to be common to different measurers, or to vary with the measurer.

To elucidate the matter the 125 stars were first measured again by Mr. B. G. C. Gray, and it was found that our mean differences were

	x B–G	y B–G
Exposure I.	·0000	·0000
Exposure II.	−·0003	+·0001

The next step taken was to arrange the differences according to diameter of the star image as in Table II.

TABLE II.

Differences between exposures (I.–II.) *arranged according to diameter of star image.*

(The unit is 0″·3 or ·001 of a réseau interval.)

Diameter of image.	No. of stars.	*x* Difference.		*y* Difference.	
		Bellamy.	Gray.	Bellamy.	Gray.
50 to 75	10	+0·1	...	+0·4	...
40 „ 49	20	+0·2	...	+0·1	...
30 „ 39	17	−0·4	...	−0·9	...
30 „ 39	7	−0·64	−0·57	−0·21	+0·43
20 „ 29	18	+0·67	+0·56	−0·12	−0·18
15 „ 19	22	+0·43	+0·35	−0·42	−0·12
11 „ 14	34	+0·75	+0·32	−0·35	−0·23
8 „ 10	32	+1·06	+0·20	−0·52	−0·36
7 and less	13	+1·30	+0·83	−1·07	−0·77

The first three groups refer to forty-seven of the fifty-one stars—the other four stars are below 30 in diameter—from the Cambridge and Leiden Catalogues; but the work was only carried to ·001 of a réseau interval, and Mr. Gray did not measure these stars. Remembering that the measures are only estimated to a unit of the above table, and therefore allowing for considerable accidental error, especially in the smaller groups, we may conclude that the table gives satisfactory evidence of a small systematic difference depending on the magnitude of the star, which may be due to the measurer or may be an outcome of the irregularities in keeping the guiding star bisected accurately during the exposure. Indeed an effect of this kind is theoretically probable in all cases; it is most unlikely that the unavoidable excursions of the guiding star will be precisely symmetrical in all directions, and any uncompensated excursion may elongate the image of a bright star slightly without affecting the image of a faint star.*

It is not possible to follow up the investigation of this difference further at present; and we must be content to take the mean of the two exposures. In Table VI. each coordinate of these 126 stars is obtained from eight measures in all; the Nova from twenty measures (two measures, two exposures, and two positions of the plate).

But since this plate does not show stars beyond about the 13·5 magnitude there have also been measured (and the

* It seems probable that this error is identical with that mentioned as a "guiding error" on p. 30 of Publication No. 10 of the Astronomical Laboratory at Groningen, just received. But we have not yet received Publication No. 1 in which this error is defined.

es incorporated in Table VI.), forty-one fainter stars onl
on the plate with 100^m exposure, as will now be described

Plate 2240.

posed for 100^m on 1903 April 22. In the small square of
' surrounding the Nova fifty-seven stars were measured,
ne of which are not visible for measurement on plate 2222.
cial interest are the six stars measured by Professor E. E.
d (*Yerkes Obs. Bulletin*, No. 19, or *Astroph. Journ.* xvii.
, reference to which may be facilitated by the following
—

TABLE III.

arnard's (B. No. 19) Magnitude.	Pickering's (Harv. Circ. No. 70) Ref. No.	Pickering's (Harv. Circ. No. 70) Magnitude.	Oxford (TABLE VI.) Ref. No.	Oxford (TABLE VI.) Diameter on plate 2240.	Inferred magnitude.
12·3	γ	13·53	83	16	13·5
12·6	—	—	80	10	14·5
14·5	—	—	75	4	15·5
12·5	β	13·35	74	18	13·0
12·5	—	—	68	19	12·8
12·0	α	13·05	82	18	13·0

ering's three stars α, β, γ are visible on plate 2222. If
me that Barnard's estimates are numerically 1 magnitude
ll the faint star 3 (Oxford 75), which is just visible on
40, is of about magnitude 15·5. The star 2, estimated
ard as equally bright with 1 and 4, is photographically
y a magnitude or more.

ires of the Nova on plate 2240 were made by Mr. H. C.
Mr. E. A. Gray, and myself, and we all used several
bisecting the image, or taking contact observations of
ter &c. The fifty-seven faint stars near the Nova were
by myself alone. For the determination of the con-
plate 2240 twelve stars were selected within 15′ of the
which standard coordinates had been deduced from
es of the first exposure of plate 2222. [The measures
d exposure were not at this time available.] Com-
he measures of these twelve on plate 2240 with their
ordinates gave the following plate constants :—

a_1	b_1	c_1	d_1	e_1	f_1
·00078	−·00198	+·1405	+·00122	−·00108	−·0389

stants derived from stars in a restricted area on the
give satisfactory results for stars within the area,
better results than the bright stars previously used
, the discs of which were larger than ever. But as
constants four pairs of stars about 35′ from the

plate centre were also selected for measurement, and the constants thus independently deduced were

	a_2	b_2	c_2	d_2	e_2	f_2
Solution 2	−·00072	−·00205	+·1391	+·00139	−·00094	−·0428

A comparison of the residuals from constants 1 and constants 2 is given in Table IV.

TABLE IV.

Plate 2240–2222.

Standard Coordinates.		Residuals in x Solution.		Residuals in y Solution.	
ξ_1	η_1	(1)	(2)	(1)	(2)
14·6456	10·7925	+·0007	+·0019	−·0009	−·0011
14·9803	10·8371	+ 14	+ 25	+ 11	+ 10
15·6151	10·6177	− 18	− 7	− 11	− 12
19·8740	10·6610	− 9	0	0	− 9
20·4223	11·1470	− 3	+ 7	+ 4	− 8
20·5139	11·0765	+ 6	+ 16	+ 7	− 4
20·7052	15·9783	− 4	+ 8	− 1	− 19
19·5020	16·2573	+ 4	+ 17	+ 2	− 18
20·5336	16·3616	+ 3	+ 16	− 8	− 26
16·0666	16·5058	+ 1	+ 17	+ 17	+ 5
14·9455	16·0547	+ 11	+ 27	− 12	− 21
15·0960	15·8960	− 18	− 3	+ 5	− 4
Mean . .		·0000	+ 0012	·0000	− ·0010
6·4020	13·1041	−·0020	−·0001	−·0005	+·0005
5·8247	12·1288	− 11	+ 8	− 9	+ 1
19·8401	12·4597	− 10	+ 1	+ 30	+ 16
19·4214	12·5416	− 4	+ 6	+ ·1	- 11
12·6467	20 3089	− 28	− 6	+ 20	+ 8
13·8514	20·6995	− 22	− 2	− 1	− 17
13·3988	7·3208	− 9	+ 2	− 3	+ 1
14·1247	7·0919	− 21	− 11	− 15	− 13
Mean . .		−·0016	·0000	+·0002	−·0001

No one would probably think of using solution 1 derived from the twelve stars to obtain places of the eight stars, and some might prefer to use solution 2 both for the twelve stars and the eight stars. But the case is not so clear for the latter. The means indicate that there is a sensible mean displacement of the twelve stars relatively to the eight, which is probably similar in character to the

displacement between the two exposures already noticed in the case of plate 2222. If the cause is rightly assigned then for the faint stars near the Nova it would certainly seem preferable to use solution 1, which is derived from stars more nearly of the same brightness. Or we might possibly use solution 2 corrected by the mean values found above, which would correspond to determining scale value and orientation from stars widely separated and applying a local correction to the general region.

On the whole it was determined to use solution 1—from the twelve stars—as it stands.

The places of the Nova are

	ξ_1	η_1	R.A.	Decl.
			h m s	° ′ ″
Solution 1	17·7168	13·5372	6 37 48·98	+30 2 38·4
Solution 2	17·7181	13·5361	6 37 49·00	+30 2 38·0

It may be mentioned that when the constants a, b, d, e are corrected for differential refraction they become

	a.	b.	d.	e.
Solution 1	−·00043	−·00163	+·00157	−·00073
Solution 2	−·00037	−·00170	+·00174	−·00058

The following table (V.) gives the comparison of the positions derived from both plates for those stars which have been measured on both and not given in Table IV.

TABLE V.

Ref. No.	Diameter. Pl. 2240.	2240−2222. x.	y.	Ref. No.	Diameter. Pl. 2240.	2240−2222. x.	y.
35	41	+·0009	−·0005	81	21	+·0021	+·0007
39	21	+ 2	− 15	82	18	− 23	− 7
40	39	+ 22	− 5	101	21	− 2	+ 32
41	20	− 14	− 17	108	18	− 7	− 30
42	15	− 6	− 9	109	22	+ 8	+ 20
47	23	− 5	+ 20	114	22	+ 3	− 5
51	30	− 17	+ 2	121	34	− 7	+ 4
55	19	+ 9	− 9				

In Table VI. the positions of stars deduced from plate 2222 are entered in preference to those deduced from plate 2240, since the former depend upon eight bisections and the latter on two bisections. Positions derived from plate 2240 are marked with an asterisk to the magnitude.

The stars in Father Hagen's *Chart and Catalogue for Observing Nova Geminorum* and those given in the *Harvard Circular*, No. 70, have been identified so far as they come within the Oxford range of 15′ radius from the Nova; the number, or letter, and magnitudes are entered to the corre-

sponding stars in the Oxford Catalogue; other synonyms are given at the end.

Hagen Nos. 1 to 19, 21, 23 to 26, 29, 32 to 36, 38 to 40, 42, 45, 46, and 59 are outside the limit of the 15′ radius from the Nova, and have not been measured on the Oxford plates. I have not been able to satisfactorily identify any of the stars I have measured with Nos. 57 and 58, nor after re-examination can I find a star to agree closely with either position given. Nos. 30 (10·1 mag.) and 49 (10·9) form a double star and equal Harvard *h* (9·71). Harvard *a*, *b*, *c*, *d*, *g*, *k* are outside the 15′ limit; the others are identified.

Oxford No. 167 has been specially included, as it is Barnard's reference star used for the micrometer measures with the 40-inch refractor.

The fifth column in Table VI. contains the magnitude inferred from a comparison of the Oxford diameters—the two plates being separately treated—with the magnitudes given by Harvard, Hagen, and Barnard. These magnitudes were plotted with Oxford diameters as the argument, and are practically represented by a straight line through the points. The magnitudes in the fifth column were read off from that diagram, and are only intended to be approximately correct.

TABLE VI.

Places of 126 *stars found from Plate* 2222 *and* 41 *additional stars from Plate* 2240.

Oxford Ref. No.	Hagen No.	Harvard No.	Oxford measured diameter.	Magnitude. Inferred.	Hagen.	Harvard.	ξ' 1900·0.	η' 1900·0.	Deduced. R.A. 1900·0. h m s	N. Dec. 1900·0. ° ′ ″
1			12	12·5			14·6455	10·7932	6 36 37·93	29 48 57·6
2			15	12·1			14·6582	15·3938	6 36 38·37	30 11 57·8
3			12	12·5			14·7000	12·7556	6 36 39·25	29 58 46·3
4			18	11·7			14·7610	14·7772	6 36 40·73	30 8 52·8
5	37		29	10·5	10·4		14·8152	13·2850	6 36 41·92	30 1 24·5
6			18	11·7			14·9479	16·0553	6 36 45·09	30 15 16·1
7			18	11·7			14·9810	10·8379	6 36 45·66	29 49 10·9
8			11	12·6			15·0949	15·8957	6 36 48·50	30 14 28·2
9			7	13·2			15·1642	14·3726	6 36 50·05	30 6 51·2
10	69		18	11·7	11·5		15·2171	15·0835	6 36 51·30	30 10 24·4
11			7	13·2			15·2325	12·3740	6 36 51·53	29 56 51·6
12			9	12·8			15·2970	12·8673	6 36 53·04	29 59 19·5
13	55		20	11·5	11·1		15·6143	10·6171	6 37 0·26	29 48 4·3
14			7	13·2			15·6082	14·9459	6 37 0·34	30 9 42·9
15			20	11·5			15·7151	11·4305	6 37 2·62	29 52 8·3

No.	Harvard No.	Oxford measured diameter.	Magnitude. Inferred.	Hagen.	Harvard.	ξ′ 1900·0.	η′ 1900·0.	Deduced. R.A. 1900·0. h m s	N. Dec. 1900·0. ° ′ ″
		8	13·1			15·7661	15·3371	6 37 4·01	30 11 40·2
		20	11·5			15·9438	13·2044	6 37 7·99	30 1 0·2
53		22	11·2	11·1		15·9882	11·6652	6 37 8·94	29 53 18·5
		10	12·7			15·9860	16·0686	6 37 9·13	30 15 19·4
		8	13·1			16·0087	15·4427	6 37 9·63	30 12 11·6
54		18	11·7	11·4		16·0665	16·5062	6 37 11·03	30 17 30·7
		8	13·1			16·1353	15·8863	6 37 12·59	30 14 24·7
31	*l*	34	9·9	10·2	10·13	16·1803	13·7054	6 37 13·49	30 3 20·3
		8	13·1			16·2904	11·8839	6 37 15·92	29 54 23·8
		14	12·2			16·3079	10·9519	6 37 16·27	29 49 44·2
		10	12·7			16·3504	13·1421	6 37 17·39	30 0 41·2
51	*r*	20	11·5	11·3	11·63	16·3557	12·6059	6 37 17·47	29 58 0·4
		12	12·5			16·3942	12·8241	6 37 18·37	29 59 5·8
		9	12·8			16·3932	15·2124	6 37 18·52	30 11 2·3
		9	12·8			16·4758	13·5725	6 37 20·31	30 2 50·3
56		13	12·3	11·5		16·5041	14·5302	6 37 21·03	30 7 37·5
		12	12·5			16·5121	12·2124	6 37 21·06	29 56 2·2
		8	13·1			16·5962	16·2618	6 37 23·28	30 16 16·9
		15	12·1			16·6679	14·6652	6 37 24·82	30 8 17·9
44	*n*	30	10·3	10·7	10·66	16·6754	13·3804	6 37 24·91	30 1 52·4
		20	11·5			16·6957	12·0114	6 37 25·28	29 55 1·7
7		30	10·3	9·9		16·7057	10·8941	6 37 25·42	29 49 26·5
		9	12 8			16·7779	15·4014	6 37 27·41	30 11 58·6
		13	12·3			16·8047	13·0248	6 37 27·86	30 0 5·6
47		26	10·7	10·9		16·8141	12·4133	6 37 28·04	29 57 2·2
	x	9	12·8		12·45	16·8134	13·8450	6 37 28·13	30 4 11·7
		5	13·5			16·8158	13·4693	6 37 28·15	30 2 19·0
52		23	11·1	11·0		16·8247	11·7880	6 37 28·24	29 53 54·6
		11	12·6			16·8261	15·7081	6 37 28·55	30 13 30·6
		17 *	13·4			16·8626	14·1116	6 37 29·29	30 5 31·6
		10	12·7			16·8579	15·8402	6 37 29·30	30 14 10·2
77	*w*	16	12·0	11·7	12·23	16·8625	14·3268	6 37 29·30	30 6 36·2
		14 *	14·0			16·8836	14·1689	6 37 29·78	30 5 48·8
		7 *	15·0			16·9110	14·3271	6 37 30·42	30 6 36·2
		6 *	15·2			16·9573	13·9191	6 37 31·46	30 4 33·8

Oxford Ref. No.	Hagen No.		Harvard No.	Oxford measured diameter.	Magnitude. Inferred.	Hagen.	Harvard.	ξ' 1900·0.	η' 1900·0.	Reduced. R.A. 1900·0. h m s	N. Dec. 1900·0. ° ′ ″
51	73	*t*		19	11·6	11·6	11·78	16·9664	14·1132	6 37 31·66	30 5 32·0
52				13	12·3			16·9748	12·2427	6 37 31·74	29 56 10·8
53	68			17	11·8	11·5		16·9739	16·1773	6 37 32·02	30 15 51·2
54				13	12·3			17·0410	12·5035	6 37 33·28	29 57 29·0
55				10	12·7			17·0557	13·0124	6 37 33·67	30 0 1·7
56				9 *	14·7			17·0946	13·5336	6 37 34·60	30 2 38·0
57				16 *	13·6			17·1448	12·5410	6 37 35·68	29 57 40·1
58				8 *	14·8			17·1613	12·5440	6 37 36·06	29 57 41·0
59	43			24	11·0	10·7		17·2180	11·5484	6 37 37·29	29 52 42·3
60				9	12·8			17 2269	11·9875	6 37 37·53	29 54 54·0
61				9 *	14·7			17·2753	13·5434	6 37 38·78	30 2 40·7
62				8	13·1			17·2907	16·2645	6 37 39·36	30 16 16·9
63				9 *	14·7			17·3154	12·5628	6 37 39·62	29 57 46·5
64				17	11·8			17·3582	15·8287	6 37 40·89	30 14 6·0
65				11	12·6			17·3752	11·4044	6 37 40·91	29 51 58·9
66				11	12·6			17·3820	15·3677	6 37 41·40	30 11 48·1
67				12	12·5			17·3844	16·1307	6 37 41·53	30 15 36·8
68				19 *	13·2			17·4723	13·7699	6 37 43·35	30 3 48·5
69				11 *	14·4			17·5784	14·1742	6 37 45·84	30 5 49·6
70				6	13·3			17·5908	12·4200	6 37 45·98	29 57 3·5
71				5 *	15·3			17·5913	13·1024	6 37 46·04	30 0 28·1
72				4 *	15·5			17·6120	12·9828	6 37 46·51	29 59 52·2
73				7 *	15·0			17·6301	12·8326	6 37 46·91	29 59 7·1
74	80	*β*		18 *	13·3		13·35	17·6380	13·2692	6 37 47·13	30 1 18·1
75				4 *	15·5			17·6614	13·7142	6 37 47·71	30 3 31·6
76				6	13·3			17·6683	14·6618	6 37 47·97	30 8 15·8
77	Nova							17·7173	13·5379	6 37 48 99	30 2 38·6
78	48	*p*		25	10·8	10·9	11·19	17·7193	14·7677	6 37 49·15	30 8 47·5
79				5 *	15·3			17·7308	13·0813	6 37 49·26	30 0 21·6
80				10 *	14 6			17·7454	13·3916	6 37 49·63	30 1 54·7
81				6	13·3			17·7878	12 6121	6 37 50·54	29 58 0·8
82	79	*α*		6	13·3		13·05	17·8161	13·8672	6 37 51·31	30 4 17·2
83	81	*γ*		16 *	13·6		13·53	17·8192	13·5128	6 37 51·34	30 2 30·9
84				9 *	14·7			17·8520	12·8930	6 37 52·04	29 59 24·9
85				5 *	15·3			17·8670	13·4114	6 37 52·44	30 2 0·4

no.	Harvard No. Oxford	measured diameter.	Magnitude. Inferred.	Hagen.	Harvard.	ξ' 1900·0.	η' 1900·0.	Deduced. R.A. 1900·0. h m s	N. Dec. 1900·0. ° ′ ″
		8	13·1			17·8928	15·3043	6 37 53·22	30 11 28·3
		9 *	14·7			17·9183	12·8027	6 37 53·57	29 58 57·8
;1		25	10·8	11·0		17·9253	11·2580	6 37 53·57	29 51 14·4
		6 *	15·2			17·9706	13·1547	6 37 54·81	30 0 43·3
		13	12·3			17·9951	11·1471	6 37 55·18	29 50 41·0
		8 *	14·8			18·0051	12·6535	6 37 55·55	29 58 12·9
		8	13·1			18·0060	14·7797	6 37 55·78	30 8 50·7
		5 *	15·3			18·0299	13·8081	6 37 56·24	30 3 59·3
		9 *	14·7			18·0710	14·3579	6 37 57·24	30 6 44·1
		9 *	14·7			18·1171	14·4097	6 37 58·31	30 6 59·6
		9 *	14·7			18·1390	14·3376	6 37 58·81	30 6 38·0
		11 *	14·4			18·1842	12·8489	6 37 59·71	29 59 11·3
		13 *	14·1			18·1847	13·0967	6 37 59·75	30 0 25·6
		11 *	14·4			18·1901	12·5512	6 37 59·81	29 57 42·0
		11 *	14·4			18·2499	14·4758	6 38 1·39	30 7 19·3
	z	8	13·1		12 95	18·3204	13·3278	6 38 2·90	30 1 34·8
;7		18	11·7	11·5		18·3260	16·2598	6 38 3·34	30 16 14·3
		5 *	15·3			18·3405	14·2407	6 38 3·60	30 6 8·6
		16 *	13·6			18·3529	13·4138	6 38 3·66	30 2 0·5
		5	13·5			18·3826	11·7564	6 38 4·18	29 53 43·3
		10	12·7			18·4275	12·4931	6 38 5 29	29 57 24·2
		10	12·7			18·4157	15·4065	6 38 5·32	30 11 58·2
		5	13·5			18·4277	13·7633	6 38 5·42	30 3 45·3
		11	12·6			18·4554	12·8191	6 38 5·97	29 59 2·0
		16 *	13·6			18·4520	14·2097	6 38 6·04	30 5 59·2
		5 *	15·3			18·4714	13·5990	6 38 6·42	30 2 55·9
		7 *	15·0			18·4770	13·9158	6 38 6·58	30 4 31·0
		6 *	15·2			18·4842	12·9924	6 38 6·65	29 59 53·9
;5	*y*	8	13·1	11·7	12·76	18·6107	13 5907	6 38 9 64	30 2 53·3
		12	12·5			18·6309	11·0634	6 38 9·83	29 50 15·1
		16	12·0			18·6289	16·1998	6 38 10·34	30 15 55·9
		17 *	13·4			18·6493	12·7503	6 38 10·44	29 58 41·1
		10 *	14·6			18·6522	13·7664	6 38 10·61	30 3 45·9
		12 *	14·2			18·6621	14·1938	6 38 10·89	30 5 54·1
		11	12·6			18·6840	15·2661	6 38 11·50	30 11 15·7

Oxford Ref. No.	Hagen No.	Harvard No.	Oxford measured diameter.	Magnitude. Inferred.	Hagen.	Harvard.	ξ' 1900·0.	η' 1900·0.	Deduced. R.A. 1900·0. h m s	N. Dec. 1900·0. ° ′ ″
121	56	*g*	22	11·2	11·2	11·41	18·7368	13·0909	6 38 12·49	30 0 23·1
122			20	11·5			18·7952	16·3749	6 38 14·22	30 16 48·2
123			15	12·1			18·8243	12·5622	6 38 14·46	29 57 44·4
124			13	12·3			18·8172	16·0367	6 38 14·69	30 15 6·7
125			13	12·3			18·8994	11·9652	6 38 16·12	29 54 45·2
126	76	*s*	17	11·8	11·7	11·73	18·9057	14·6775	6 38 16·58	30 8 18·9
127			14	12·2			18·9908	14·9177	6 38 18·57	30 9 31·1
128			10	12·7			19·1165	12·7758	6 38 21·22	29 58 48·0
129	62		16	12·0	11·4		19·2276	12·2708	6 38 23·73	29 56 16·4
130	78	*u*	14	12·2	11·7	12·08	19·2654	14·0276	6 38 24·81	30 5 3·3
131			7	13·2			19·3090	10·6358	6 38 25·39	29 48 5·8
132	63		14	12·2	11·4		19·3737	13·4091	6 38 27·25	30 1 57·6
133			10	12·7			19·4074	11·1205	6 38 27·74	29 50 31·0
134	49	*h*	28	10·6	10·9	9·71	19·3959	14·5240	6 38 27·90	30 7 32·0
135	30	*h*	30	10·3	10·1		19·3969	14·4981	6 38 27·91	30 7 24·3
136(3)	41		27	10·7	10·6		19·4209	12·5410	6 38 28·23	29 57 37·1
137			11	12·6			19·5013	16·2526	6 38 30·55	30 16 10·4
138	50	*o*	22	11·2	11·0	11·01	19·5159	14·2090	6 38 30·63	30 5 57·4
139			18	11·7			19·5381	11·7121	6 38 30·83	29 53 28·3
140			13	12·3			19·6334	14·7282	6 38 33·41	30 8 32·9
141			8	13·1			19·7583	15·9519	6 38 36·46	30 14 39·8
142(4)	28	*m*	32	10·1	10·0	10·41	19·8417	12·4610	6 38 37·92	29 57 12·4
143(5)	20	*f*	41	9·2	9·4	9·14	19·8365	15·3749	6 38 38·19	30 11 46·6
144	71		14	12·2	11·6		19·8739	10·6620	6 38 38·43	29 48 12·7
145			11	12·6			19·9379	13·9164	6 38 40·34	30 4 28·8
146	54		17	11·8	11·1		19·9400	15·0680	6 38 40·54	30 10 14·3
147			10	12·7			19·9570	12·4561	6 38 40·59	29 57 10·7
148			11	12·6			19·9683	15·2567	6 38 41·23	30 11 10·9
149(6)	22		37	9·6	9·5		20·0255	11·2297	6 38 42·00	29 51 2·7
150			6	13·3			20·0914	15·4611	6 38 44·16	30 12 11·9
151			14	12·2			20·1525	12 8524	6 38 45·13	29 59 9·3
152	60		18	11·7	11·3		20·1747	15·6251	6 38 46·06	30 13 1·0
153			8	13·1			20·2612	10·7170	6 38 47·36	29 48 27·8
154			9	12·8			20·2418	16·3169	6 38 47·71	30 16 28·4
155	70		16	12·0	11·5		20·2712	12·4483	6 38 47·84	29 57 7·8

Oxford Rel. No.	Hagen No.	Harvard No.	Oxford measured diameter.	Magnitude. Inferred.	Hagen.	Harvard.	ξ' 1900·0.	η' 1900·0.	Deduced. R.A. 1900·0.	N. Dec. 1900·0.
									h m s	° ′ ″
156	65		19	11·6	11·5		20·2864	11·5035	6 38 48·05	29 52 24·4
157			8	13·1			20·3600	11·1597	6 38 49·71	29 50 41·2
158			20	11·5			20·3441	15·4441	6 38 49·95	30 12 6·4
159			14	12·2			20·4220	11·1478	6 38 51·13	29 50 37·5
160			8	13·1			20·4377	13·3508	6 38 51·81	30 1 38·3
161			13	12·3			20·5135	11·0773	6 38 53·23	29 50 16·1
162	74		12	12·5	11·7		20·5379	12·6067	6 38 54·01	29 57 54·9
163			17	11·8			20·5337	16·3609	6 38 54·47	30 16 41·0
164			9	12·8			20·5491	15·9938	6 38 54·78	30 14 50·9
165			8	13·1			20·6119	12·0151	6 38 55·64	29 54 57·3
166			13	12·3			20·7040	15·9787	6 38 58·36	30 14 46·1
167	3	*e*	46	8·6	7·9	8·82	23·8665	12·3901	6 40 10·80	29 56 42·1

Notes.

(1) No. 23 is B.D. + 30°, 1309. (2) B.D. + 29°, 1324. (3) B.D. + 30°, 1315.
(4) B.D. + 30°, 1317. (5) B.D. + 30°, 1316. (6) B.D. + 29°, 1328.
No. 68 is Barnard's No. 5; No. 74 = No. 4; No. 75 = No. 3; No. 80 = No. 2; No. 82 = No. 6; and No. 83 = No. 1.
Nos. 134 and 135 form a double star, the images coalescing with the 30ᵐ and 35ᵐ exposures; Harvard gives the combined light (9·71) for these two.

Four stars of the 10th magnitude or brighter with the following measured coordinates in x and y

	x	y
Camb. 3447, B.D. + 30°, 1306, Harvard *g*, Hagen 11,	14·409	13·960
„ „ B.D. + 30°, 1309, „ *l*, „ 31,	16·229	13·665
Camb. 3467, B.D. + 30°, 1316, „ *f*, „ 20,	19·883	15·335
Leiden 2803, B.D. + 30°, 1320, „ *d*, „ 15,	21·134	16·433
Nova	17·766	13·498

from the first exposure of plate 2222 lie in two lines from the Nova, and serve as two pairs of pointers for detecting the position of the Nova. A line passing through each pair to the Nova is so straight that by taking the two outside stars and calculating from the measured x of the middle one, the y for a straight line, we get the calculated $y = \cdot212 + \text{Nova}$, observed $y = \cdot167 + \text{Nova}$, $O - C = -\cdot045 = -13''\cdot5$; for the other the calculated is 1·845, observed 1·837, $O - C = -\cdot008 = -2''\cdot4$. We have frequently found them useful in ascertaining the region and for determining the orientation of the photograph. The

R.A. and Decl. of B.D. + 30°, 1306, is $6^h\ 36^m\ 31^s{\cdot}44 + 30°\ 4'\ 59''{\cdot}4$, and of B.D. + 30°, 1320 R.A. is $6^h\ 39^m\ 7^s{\cdot}30$, Decl. + 30° 17′ 13″·6. The other two stars have already been given in the catalogue under No. 23 and 143.

University Observatory, Oxford:
1903 *June* 12.

On the Position of X Geminorum. By F. A. Bellamy.

This star is on both the plates (2222 and 2240) discussed in the preceding paper, and the measures and reductions have been made in precisely the same way.

Stars No. 5, 6, 7, were measured, both exposures, on plate 2222, and corrected for the mean of the two sets of constants derived from the first and second set of exposures; stars 1 to 9 were measured on plate 2240. The positions 1 to 4, 8 and 9 depend upon direct and reverse measures on the latter plate only, 5, 6, and 7 are the means of the measures on both plates. The following are the positions (1900·0) for these few stars near *X Geminorum*:

Oxford No.	Diameter.	Inferred Mag.	Standard Coordinates. ξ_1	η_1	Deduced. R.A. 1900·0. h m s	Decl. 1900·0. ° ′ ″
1	15	13·8	24·8481	17·2664	6 40 34·57	+ 30 21 2·0
2	17	13·4	24·9145	17·4173	36·14	21 47·0
3	5	15·3	25·0267	17·4543	38·75	21 57·8
4	7	15·0	25·0565	17·3201	39·41	21 17·4
5	31	11·8	25·0722	17·4325	39·80	21 51·0
6	23	12·5	25·1959	17·8365	42·76	23 51·9
7	28	12·0	25·2112	17·6554	43·08	22 57·5
8	12	14·2	25·2426	17·8293	43·85	23 49·6
9	32	11·2	25·5909	18·0591	51 98	24 57·4

The 7th star best agrees with the approximate place of *X Geminorum* as usually given; but in the case of variable star regions which are rich with stars, especially faint ones, there is some uncertainty about the identification; but I could find no other star nearer to R.A. $6^h\ 40^m\ 43^s + 30°\ 22'{\cdot}6$ * than that given for No. 7, and stars 5, 6 and 9 of the above list agree with *e*, *g* and *d* respectively of Mr. Parkhurst's paper in *A.J.* No. 428.

University Observatory, Oxford:
1903 *June* 12.

* *Astronomical Journal*, No. 428, vol. xviii. p. 160, and No. 514, vol. xxii. p. 78.

On the Relation existing between the Light Changes and the Orbital Elements of a close Binary System, with special reference to the Figure and Density of the Variable Star RR Centauri. By Alex. W. Roberts, D.Sc.

The number of *Algol* variables, with the peculiar property of rapid and continuous variation recently discovered, brings into prominence the interesting problem of the relation of light variation to orbital movement. The refinement also and completeness which is now rightly insisted on in the observation of any cycle of light changes, due evidently to the eclipse of one star by another, makes the investigation of the problem a more hopeful matter than it would have been several years ago.

The problem is not only of considerable interest, it is also of great importance. Indeed, the determination of the figure of a close binary star solely from the character of the light changes produced by the alternating eclipse of the component bodies is one of no ordinary significance in the present progressive state of astrophysical research. It is an investigation which leads us directly to the wider problem of stellar evolution.

It is also evident that a complete solution of the problem is one of no small difficulty; not because the equations which connect the light variation of a close binary and its orbital elements are of an indefinite character, but because the numerical quantities on which the evaluation of these equations depends are exceedingly small.

Thus the problem, even in its simplest form—that is, when it deals with the revolution of two stars practically in contact—comprises at least the determination of six unknown quantities, representing the figure, relative brightness, relative size, and relative distance of the twin stars. For the determination of these six unknown terms we have only as our argument a variation never much greater than half a magnitude.

That this meagre ebb and flow would yield data for the complete detection of the causes which have produced it, or of the conditions of figure and orbit which have given it a special character, is not to be expected. Yet, although a complete solution of the problem cannot be hoped for at present, it will be helpful, I think, to indicate the amount of certainty that we may reasonably assure ourselves of, and at the same time to state the limitations to the full exposition of the problem which we know to exist.

Put simply, the problem to be solved is this: From the light variation of any close binary system, as determined by observation, to ascertain the orbit and relative dimensions, and also the figure and density of the two stars forming the system.

At the very outset of the inquiry we are compelled to make

two or three assumptions, more or less reasonable in their nature. In the present state of our knowledge we cannot deal otherwise with the problem. Further, a conditioned investigation is more conclusive than one that is controlled by no reasonable limitations.

We assume, *first*, that the light changes of all variable stars of the *Algol* type are caused by the revolution of one star round another. Where such proof is possible the spectroscope has furnished it. It is not possible, of course, to deal spectroscopically with the light of faint stars, but when the light curve of such stars is identical in type and character with the light curve of certain bright stars that are proved to be binary, it is not unreasonable to assume that these fainter stars also are binary systems.

Then, *secondly*, we assume that all portions of the surface of a close binary system are equally luminous, and that, also, there is no outer atmospheric envelope absorbing a portion of the light from a bright interior globe. The gaseous density of nearly all *Algol* variables is urged in support of this contention.

The *third* assumption is one which is made necessary by the nature of the problem. We assume that the figures of two stars revolving round each other contiguously are prolate spheroids of revolution with two unequal axes. The problem is indeterminate if we attempt to deal with an ellipsoid of revolution with three unequal axes. The consideration of an irregular figure is, of course, out of the question: an investigation of this nature premises observations correct to within $0^{m}\cdot001$, a refinement of accuracy far beyond our present reach.

It would have been possible to deal with the problem otherwise than postulating at least two of the conditions just stated. We could have assumed figures of equilibrium such as Professor Darwin deduced from theoretical considerations alone in his classical investigation "On the Figure of Equilibrium of Rotating Masses of Fluid," and we could have enshrouded these bodies with atmospheres so constituted that they would absorb just the right amount of light to make theory agree with observation. Such a mode of reconciling theory and observation, while not lacking in suggestiveness, would certainly be wanting in finality.

On the other hand, it may be contended against the plan of inquiry adopted in the present investigation, basing our system of connecting equations on two conditions not absolutely in accord with theory, or which cannot be rigorously demonstrated as tenable, that there will be a certain inconclusiveness in the solutions arrived at.

This is to a certain extent true; the weight of the objection, however, depends on the extent to which a possible inaccurate assumption, or an uncertain condition, introduces error into our conclusions. That the acceptance of the two assumptions just stated will introduce an element of uncertainty into the investigation may be possible, but the uncertainty ranges within very narrow limits. It is of the same order as the

assumption that the Earth's orbit is circular in problems dealing with stellar parallax.

Further, without some conditioned solution the problem is insoluble. This will be made evident as the investigation proceeds.

After stating the theory of the relation of light variation to orbital movement, I purpose taking, as a special application of the various formulæ employed, the light changes of the variable star

Ch 5099 *RR Centauri*

$14^h\ 9^m\ 55^s$
$-57°\ 23'{\cdot}3$ } 1900

and from these light changes deducing the form of the orbit, and the figure and brightness of the component stars.

I. *Statement of the Equations connecting Light Variation with the Orbital Movement and Dimensions of a close Binary System.*

The typical close binary system may be considered as two stars, equal in size and brightness, spherical in figure, revolving round each other in, or nearly in, contact in an orbit whose plane is at right angles to the tangential plane. The typical light curve of such a system is represented in fig. 1.

TYPICAL LIGHT CURVE OF A CLOSE BINARY SYSTEM.

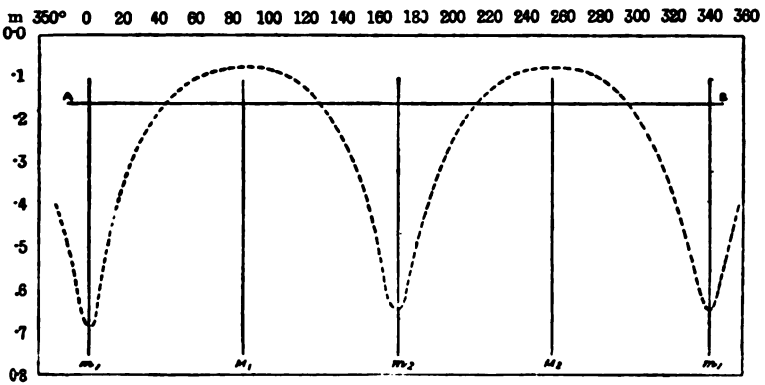


FIG. 1.

The salient features of all curves of this type are : Continuous variation, indicating that the component stars are in contact; a considerable decrease in magnitude before the mediate line AB, fig. 1, is reached, indicating that the stars depart considerably from the spherical form; two maxima and two minima phases, indicating that the stars are both lucid; an equal duration of

time between the four points of the curve, m_1 M_1 m_2 M_2, indicating that the orbit of the system is practically circular.

To this typical light curve conform in a marked degree the light curves of

β Lyræ (*Astrophysical Journal*, vol. vii. p. 1).
U Pegasi (*Astrophysical Journal*, vol. viii. p. 170).
V Puppis (*Astrophysical Journal*, vol. xiii. p. 181).
X Carinæ and *RR Centauri*.

It will be evident, however, that while the light curves of these stars possess the general family likeness of the class to which they belong, they will also be marked by distinct individual differences depending on the eccentricity and inclination of the orbit in which the component stars move, as well as on the figure, brightness, and size of the stars.

TYPICAL ORBIT OF A CLOSE BINARY SYSTEM. ECCENTRICITY = 0·07.

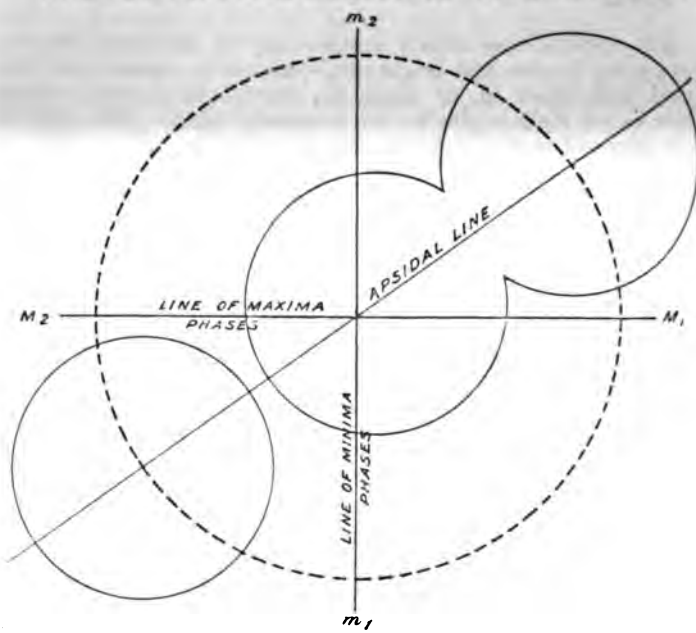


FIG. 2.

It has already been stated that *Algol* stars varying continuously cannot move in an eccentric orbit. This requires little demonstration. For let us consider as a typical system that represented in fig. 2. In this fictitious system the eccentricity

is only 0·07, but one result of this slight departure from a circular path would be a stationary period of at least one-tenth the duration of the full period of variation. An eccentricity larger than this would produce a correspondingly longer stationary period at either or both of the two maxima.

For orbits of small eccentricity a limiting relation can be thus exhibited: If P represents the full period of variation, S the duration of the stationary period at either M_1 or M_2, and e the eccentricity of the system, then

$$(1) \qquad \sqrt{e} < \frac{\pi S}{P}.$$

It is evident, therefore, that the eccentricity of a close binary system need not give us much concern. Still if the determination of the eccentricity be a matter of curiosity, there are definite data to go upon.

We have four dates as argument, viz. the instants of passage through the four points, M_1, m_2, M_2, and m_1, fig. 2.

By the fundamental law of elliptic motion the areas of the four quadrants deliminated by the lines m_1, m_2 and M_1, M_2 will be proportionate to the times of describing them. That is, the problem resolves itself into constructing an ellipse, four quadrants of which will be proportionate in area to the times taken to pass from m_1 to M_1, from M_1 to m_2, from m_2 to M_2, and from M_2 to m_1. If these four periods are equal then the orbit must be circular; if the periods are markedly unequal the orbit is eccentric, and periastron lies in the quadrant that is described in the shortest time.

The well-known formulæ of elliptical motion will in the latter case determine the eccentricity and the position of periastron, since t_1, t_2, t_3, t_4, the instants of passage through M_1, m_2, M_2, m_1, are known. Thus if we take

m° = hourly mean motion in orbit,

t_0 = instant of periastron passage (taken for example in the first quadrant),

by neglecting higher powers of e, we readily get

$$(2) \qquad \begin{cases} \pi - 2(t_2 - t_1)m^\circ = 4e\{\sin(t_2 - t_0)m^\circ - \sin(t_1 - t_0)m^\circ\} \\ \pi - 2(t_3 - t_2)m^\circ = 4e\{\sin(t_3 - t_0)m^\circ - \sin(t_2 - t_0)m^\circ\} \\ \pi - 2(t_4 - t_3)m^\circ = 4e\{\sin(t_4 - t_0)m^\circ - \sin(t_3 - t_0)m^\circ\} \end{cases}$$

In the case of all close binary stars known up to the present time

$$(t_2 - t_1)m^\circ : (t_3 - t_2)m^\circ : \text{and } (t_4 - t_3)m^\circ$$

are practically equal to 90°, that is, they move, as we should expect, in circular orbits.

We now proceed to consider the equations connecting the

light variation of a close binary system with the figure, relative size, brightness, and distance of the component stars.

In any close binary system let

P=Period of variation.

E=Epoch of principal minimum phase.

T=Any time T of an observation.

ι=Inclination of orbit to plane of sight.

ac=Semi-axis-major of star$_{(1)}$.

$\lambda\, ac$=Semi-axis-major of star$_{(2)}$.

ε=Eccentricity of figure of revolution of either $S_{(1)}$ or $S_{(2)}$.

a_1=Projected or apparent semi-axis-major of $S_{(1)}$ at time T.

a_2=projected or apparent semi-axis-minor of $S_{(2)}$ at time T.

d=Apparent distance between centres of $S_{(1)}$ and $S_{(2)}$ at time T.

ϕ=Angular distance of S_1 or S_2 at time T from line of sight.

Then the following relations will be readily established :—

(3) $\phi = \left(\frac{\pm E \mp T}{P}\right) 360°$. **This holds good only for a circular orbit.**

(4) $d = \sqrt{1-\cos^2\phi\cos^2\iota}$

(5) $a_1 = ac\sqrt{1-\cos^2\phi\cos^2\iota\,.\,\varepsilon^2}$

(6) $a_2 = \lambda\, ac\sqrt{1-\cos^2\phi\cos^2\iota\,.\,\varepsilon^2}$

Also for simplification let

(7) $\kappa = \sqrt{1-\cos^2\phi\cos^2\iota\,.\,\varepsilon^2}$

(8) $\cos\theta_1 = \frac{d^2+a_1^2-a_2^2}{2a_1 d}$

(9) $\cos\theta_2 = \frac{d^2+a_2^2-a_1^2}{2a_2 d}$

$2\theta_1$ and $2\theta_2$ are the eccentric angles subtended by the common chord of the two auxiliary circles whose diameters are a_1 and a_2.

It follows therefore that the portion of any one of the stars eclipsed by its companion at time T will be :

(10) $$\left\{\frac{a_1\beta_1}{2}(2\theta_1-\sin 2\theta_1)+\frac{a_2\beta_2}{2}(2\theta_2-\sin 2\theta_2)\right\}$$

If now we regard S_1 as being eclipsed by S_2, the uneclipsed portion of S_1 will be

$$\pi a_1\beta_1-\left\{\frac{a_1\beta_1}{2}(2\theta_1-\sin 2\theta_1)+\frac{a_2\beta_2}{2}(2\theta_2-\sin 2\theta_2)\right\}$$

Regarding L_1 as the total light of S_1 when its axis-major is at right angles to the line of sight, it is evident that the light of the uneclipsed portion of S_1 at time T is

$$L_1 \cdot \frac{\pi a_1\beta_1 - \left\{\frac{a_1\beta_1}{2}(2\theta_1 - \sin 2\theta_1) + \frac{\lambda^2 a_1\beta_1}{2}(2\theta_2 - \sin 2\theta_2)\right\}}{\pi ac \cdot \beta c}$$

$$= L_1\left[\kappa - \frac{\kappa}{2\pi}\left\{(2\theta_1 - \sin 2\theta_1) + \lambda^2(2\theta_2 - \sin 2\theta_2)\right\}\right]$$

To this quantity we have to add the light of the eclipsing star S_2 at time T, which is

$$(1 - L_1) \cdot \frac{a_2\beta_2}{\lambda ac \cdot \beta c_2}$$

$$= (1 - L_1)\kappa.$$

The total light of the system at any time T when S_2 eclipses S_1 is therefore

$$(1 - L_1)\kappa + L_1\left[\kappa - \frac{\kappa}{2\pi}\{(2\theta_1 - \sin 2\theta_1) + \lambda^2(2\theta_2 - \sin 2\theta_2)\}\right],$$

that is

$$(11) \qquad \kappa - \frac{L_1\kappa}{2\pi}\{(2\theta_1 - \sin 2\theta_1) + \lambda^2(2\theta_2 - \sin 2\theta_2)\}.$$

In the case where S_1 eclipses S_2 the uneclipsed portion of S_2 will be

$$\pi a_2\beta_2 - \left\{\frac{a_1\beta_1}{2}(2\theta_1 - \sin 2\theta_1) + \frac{a_2\beta_2}{2}(2\theta_2 - \sin 2\theta_2)\right\}$$

and the light given out by this uneclipsed area will be

$$L_2 \cdot \frac{\pi a_2\beta_2 - \left\{\frac{a_1\beta_1}{2}(2\theta_1 - \sin 2\theta_1) + \frac{\lambda^2 a_1\beta_1}{2}(2\theta_2 - \sin 2\theta_2)\right\}}{\pi\lambda^2 ac \cdot \beta c}$$

$$= L_2\left[\kappa - \frac{\kappa}{2\pi\lambda^2}\{(2\theta_1 - \sin 2\theta_1) + \lambda^2(2\theta_2 - \sin 2\theta_2)\}\right];$$

while the light from the whole system at any time T when S_1 eclipses S_2 will be

$$L_1\kappa + (1 - L_1)\left[\kappa - \frac{\kappa}{2\pi\lambda^2}\{(2\theta_1 - \sin 2\theta_1) + \lambda^2(2\theta_2 - \sin 2\theta_2)\}\right]$$

that is

$$(12) \qquad \kappa - \frac{(1 - L_1)\kappa}{2\pi\lambda^2}\{(2\theta_1 - \sin 2\theta_1) + \lambda^2(2\theta_2 - \sin 2\theta_2)\}.$$

Putting now

$$(13) \qquad q = \{(2\theta_1 - \sin 2\theta_1) + \lambda^2(2\theta_2 - \sin \theta_2)\}$$

and adopting the symbol L_o to indicate the light at any time T, then

when S_2 eclipses S_1

$$L_o=\kappa\left(1-\frac{L_1 q}{2\pi}\right). \tag{14}$$

And when S_1 eclipses S_2,

$$L_o=\kappa\left(1-\frac{(1-L_1)\,q}{2\pi\lambda^2}\right). \tag{15}$$

Also if M_o signifies the theoretical magnitude of the system at any time T, then

$$M_o=2{\cdot}512\,(10-\log L_o)+M, \tag{16}$$

where M is the maximum brightness of the system, and 2·512 the light ratio between two consecutive magnitudes.

The preceding equations indicate the series of relations that connect the changes in magnitude of any close binary system with the relative brightness, size, and magnitude of the component stars, premising the three conditions already stated.

It may be of service, in applying these equations, to collect them in an ordered sequence.

$$\phi=\left(\frac{\pm E\pm T}{P}\right)360^\circ \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (3)$$

$$d=\sqrt{1-\cos^2\phi\cos^2 i} \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (4)$$

$$a_1=ac\sqrt{1-\cos^2\phi\cos^2 i\,.\,\epsilon^2} \quad \ldots\ \ldots\ \ldots\ \ldots \quad (5)$$

$$a_2=\lambda\,.\,ac\sqrt{1-\cos^2\phi\cos^2 i\,\epsilon^2} \quad \ldots\ \ldots\ \ldots\ \ldots \quad (6)$$

$$\cos\theta_1=\frac{d^2+a_1^2-a_2^2}{2a_1d} \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (8)$$

$$\cos\theta_2=\frac{d^2+a_2^2-a_1^2}{2a_2d} \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (9)$$

Putting

$$\kappa=\sqrt{1-\cos^2\phi\cos^2 i\,.\,\epsilon^2}. \quad \ldots\ \ldots\ \ldots\ \ldots \quad (7)$$

and

$$q=(2\theta_1-\sin 2\theta_1)+\lambda^2(2\theta_2-\sin 2\theta_2) \quad \ldots\ \ldots\ \ldots \quad (13)$$

when S_2 eclipses S_1

$$L_o=\kappa\left(1-\frac{L_1 q}{2\pi}\right) \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (14)$$

and when S_1 eclipses S_2

$$L_o=\kappa\left(1-\frac{(1-L_1)\,q}{2\pi\lambda^2}\right) \quad \ldots\ \ldots\ \ldots\ \ldots \quad (15)$$

$$M_o=2{\cdot}512\,(10-L_o)+M \quad \ldots\ \ldots\ \ldots\ \ldots \quad (16)$$

The method of applying these formulæ that I have found most serviceable in investigating the orbits of southern *Algol* systems has been that of successive approximations, and then correcting the final result by a system of partial differential equations. It is only possible, of course, to push the latter refinement of treatment in the case of one or two stars.

As a first approximation, for example, we might consider, as we have already done in determining the typical light curve of this class of variable, that the stars are spherical in figure, equal in size and brightness, and revolving in contact.

Taking m_0 as the mean between m_1 and m_2, and $\phi = 0°$, we have the following simple determination of the inclination of the orbit :—

$$(17)\quad \begin{cases} \log L_0 = 10 + 0{\cdot}398\,(M - m_0) \\ (2\theta - \sin 2\theta) = 2\pi\,(1 - L_0) \\ \cos i = \sqrt{1 - \cos^2\theta} \end{cases}$$

I have found it most convenient in practice, however, to determine the prolateness of the stars, and the inclination of their orbit simultaneously by a set of tables the framework of which I subjoin.

TABLE I.

	$\epsilon^2 =$									
	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
$i = 0°$	0·756	0·813	0·877	0·950	1·034	1·134	1·255	1·412	1·634	2·012
10	·539	·585	·635	·691	0·754	0·827	0·915	1·020	1·161	1·371
20	·368	·404	·443	·486	·533	·587	·649	0·723	0·816	0·943
30	·237	·265	·295	·328	·364	·404	·448	·500	·563	·641
40	·141	·162	·185	·210	·236	·264	·296	·331	·372	·420
50	·074	·089	·106	·123	·141	·161	·182	·204	·229	·257
60	·032	·042	·053	·064	·075	·086	·098	·111	·125	·140
70	·010	·015	·020	·025	·030	·036	·042	·048	·054	·061
80	·002	·003	·004	·006	·007	·009	·010	·011	·013	·015
90	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000

TABLE II.

	$\epsilon^2 =$									
	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
$i = 0°$	0·106	0·124	0·142	0·162	0·184	0·208	0·234	0·263	0·295	0·332
10	·098	·116	·135	·155	·176	·199	·224	·252	·283	·319
20	·083	·099	·116	·134	·154	·175	·198	·223	·250	·281
30	·063	·077	·091	·107	·124	·141	·160	·181	·203	·228
40	·041	·053	·065	·077	·090	·104	·118	·134	·151	·169

	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
50°	·024	·032	·040	·050	·059	·069	·079	·090	·101	·113
60	·011	·016	·022	·027	·033	·039	·045	·052	·059	·066
70	·003	·006	·009	·012	·015	·017	·020	·023	·026	·029
80	·001	·001	·002	·003	·004	·004	·005	·006	·007	·007
90	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000

Table I. gives the decrease in magnitude at minimum, as compared with the maximum brightness, for every 10° of inclination, and every 0·1 of ϵ^2; while Table II. gives the decrease in brightness for the same arguments when the eclipse is half through, that is, when $\phi = 45°$.

The application of these tables will be better exemplified by taking a concrete example.

RR Centauri is at a maximum $7^m{\cdot}37$; halfway through the eclipse it is $7^m{\cdot}53$; and the mean of the primary and secondary minima is $7^m{\cdot}80$.

That is, we take from Table I. for a decrease of $0^m{\cdot}43$, the values of ι corresponding to each tenth of ϵ^2; and from Table II. we take the values of ι and ϵ^2 for a decrease of $0^m{\cdot}16$.

These values are :—

Table III.

decrease = $0^m{\cdot}43$

when ϵ^2 = 0·0	ι = 16°·0
0·1	18·3
0·2	20·7
0·3	23·2
0·4	25·8
0·5	28·4
0·6	31·0
0·7	33·6
0·8	36·3
0·9	39·2

Table IV.

decrease = $0^m{\cdot}16$

when ϵ^2 = 0·3	ι = 7°·0
0·4	16·7
0·5	24·5
0·6	30·0
0·7	34·4
0·8	38·0
0·9	41·5

Charting down these values, as in fig. 3, we find that they coincide when

$$\iota = 32°{\cdot}3$$
$$\epsilon^2 = 0{\cdot}65$$

The other elements, ac, λ, L_1, L_2, can be now readily obtained from the formulæ.

This first approximation may be emended by varying the elements, and thus constructing equation of condition. For most stars this will be a needless and profitless refinement.

I would seek now to make a rigorous application of the foregoing to the case of the variation of *RR Centauri*, not only for the purpose of obtaining fuller knowledge of this star, but also for the purpose of ascertaining how far we can carry our investigation, and how definite and certain the results obtained are.

GRAPHICAL DETERMINATION OF ECCENTRICITY AND INCLINATION.

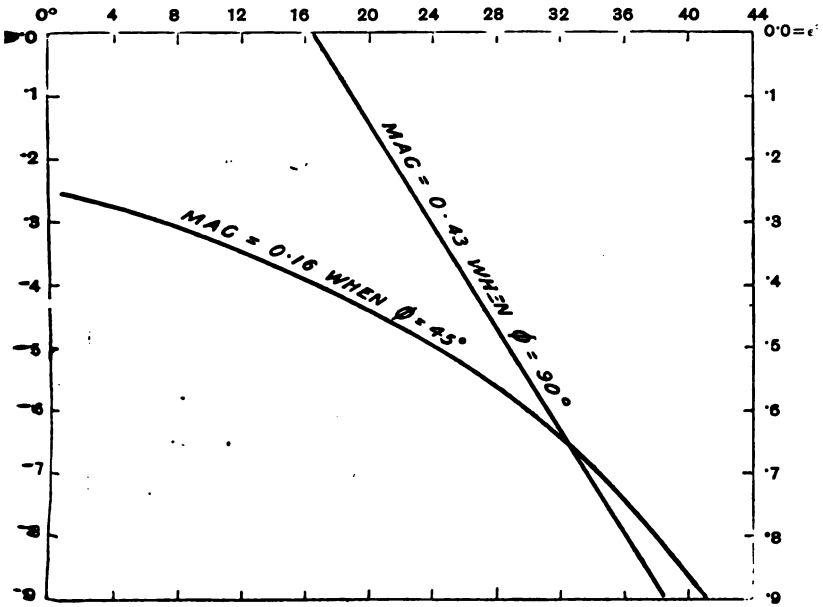


FIG. 3.

II. *Light Curve of RR Centauri as deduced from Observations taken in* 1901 *April, May, and June.*

In the months of April, May, and June 1901 a series of observations of this star were taken with the prismatic equatorial. This telescope admits of the field being rotated through any angle.

In order to eliminate the troublesome effects of position error six pointings were made each observation, the field being rotated through 60° each setting. A single observation is held to be the mean result of all the six pointings.

Five comparison stars were used in estimating the brightness of the variable, and thus for each observation thirty-six light determinations, or rather sequences, were made. Considerably over 300 observations were secured in the three months referred to, aggregating at least 12,000 light determinations.

The five comparison stars used are those dealt with in "An Investigation concerning the Position Error affecting Eye-estimates of Star Magnitudes" (*Monthly Notices*, vol. lvii. p. 485), viz.—

A. Z. C. XIV. 505	Lac. 5859	Mag. 7·24
639	5870	·40
837	5888	·57
259	5834	·62
512	—	7·87

The mode of reducing the observations employed is that described in the same paper, p. 486. This method, though laborious, ensures all the determinations of brightness being reduced to the same standard and scale. In making the observations every precaution was taken to guard against error, both irregular and systematic. Thus, in order to prevent bias influencing the determinations I closed my mind to all knowledge of the time and character of the star's variation.

I simply started observations each clear evening about seven o'clock, and went on steadily observing at intervals of twenty minutes for about eight hours. The observations were then set aside *unreduced*, and they remained unreduced until the whole series was completed. In my judgment an ephemeris of variable stars should be used as seldom as possible.

A comparison of minima determinations extending over five years gave as the period of *RR Centauri* :—

$$14^h\ 32^m\ 10^s{\cdot}76$$

With this period all the observations taken in 1901 April, May, and June were reduced to the mean curve of 1900 Jan. 1 and then grouped into twenty-nine equidistant mean places. In the formation of these mean places second differences were employed, the necessary values being furnished by a graphical mean curve.

It may be said here that while the twenty-nine mean places thus obtained represent the mean light curve of *RR Centauri*, there is manifestly an irregular, or rather regular but undetermined, secondary variation in the amplitude of the star's variation which modifies, within narrow limits, the several light curves.

The twenty-nine mean places of *RR Centauri* are as follows :—

TABLE V.

No.	Date G.M.T. 1900 d. h. m.	Observed mean mag.	Theoretical Mag. Elements III. Mag.	O−C.
1	Jan. 1 0 17	7·710	7·700	+0·010
2	47	·770	·777	−0·007
3	1 18	·810	·804	+0·006

No.	Date G.M.T. 1900 d. h. m.	Observed mean mag.	Theoretical Mag. Elements III. Mag.	O−C.
4	47	·760	·760	0·000
5	2 15	·670	·679	−0·009
6	44	·570	·586	−0·016
7	3 15	·490	·498	−0·008
8	46	·450	·432	+0·018
9	4 16	·410	·393	+0·017
10	48	·370	·376	−0·006
11	5 14	·370	·382	−0·012
12	48	·440	·418	+0·022
13	6 17	·470	·471	−0·001
14	47	·550	·547	+0·003
15	7 16	·630	·631	−0·001
16	49	·710	·723	−0·013
17	8 20	·770	·775	−0·005
18	48	·770	·764	+0·006
19	9 12	·720	·718	+0·002
20	46	·620	·620	0·000
21	10 14	·540	·537	+0·003
22	48	·460	·457	+0·003
23	11 19	·390	·405	−0·015
24	46	·370	·381	−0·011
25	12 18	·370	·377	−0·007
26	48	·390	·398	−0·008
27	13 17	·450	·442	+0·008
28	45	·510	·504	+0·006
29	1 14 19	7·610	7·603	+0·007

If the observed magnitudes given in the foregoing table are plotted down, after the usual manner, we shall have as the light curve of *RR Centauri* the distinctive curve represented in fig. 4. (Plate 21.)

It may be stated here, in connection with this figure, that the dotted line represented in the chart is the theoretical curve determined from the system of orbital elements finally arrived at in this investigation. We have, therefore, in fig. 4 (Plate 21) a graphical representation of the agreement between theory and observation.

A numerical indication of the conformity between observed and deduced magnitudes is set forth in cols. 4 and 5 of the above table.

We proceed now to consider the several steps in the determination of this theoretical curve.

III. *Determination of the Orbital Elements of RR Centauri from its observed Light Curve.*

If in fig. 4 (Plate 21) a mean curve be drawn through the observed magnitudes it will readily furnish the four dates necessary for a determination of the eccentricity of the orbit, viz.—

	d.	h.	m.
Instant of m_1 = 1900 Jan.	1	1	16 = t_1
M_1		4	55 = t_2
m_2		8	32 = t_3
Instant of M_2 =	1	12	10 = t_4

There follows therefore :

	h.	m.
t_2-t_1 =	3	39
t_3-t_2 =	3	37
t_4-t_3 =	3	38
t_1-t_4 =	3	38

These four values represent the areas of four quadrants of the orbit. But since the four areas are practically equal, it follows that the orbit of *RR Centauri* does not depart sensibly from the circular form.

We can arrive at this conclusion otherwise. It is evident from the light curve that there cannot be at either maxima a stationary period of 30^m duration. That is, from equation (1)

$$\sqrt{e} < \frac{\pi \cdot 30^m}{14^h\ 32^m}$$

$$\therefore \sqrt{e} < 0{\cdot}11$$

from which we discover that the eccentricity of *RR Centauri* cannot in any case be greater than

$$0{\cdot}01,$$

and of course may be very much less.

There is conclusive evidence, therefore, that *RR Centauri* revolves in a practically circular orbit.

We have already on page 536 arrived at a first approximation of the prolateness of the figure of the stars, and of the inclination of the orbit in which they move.

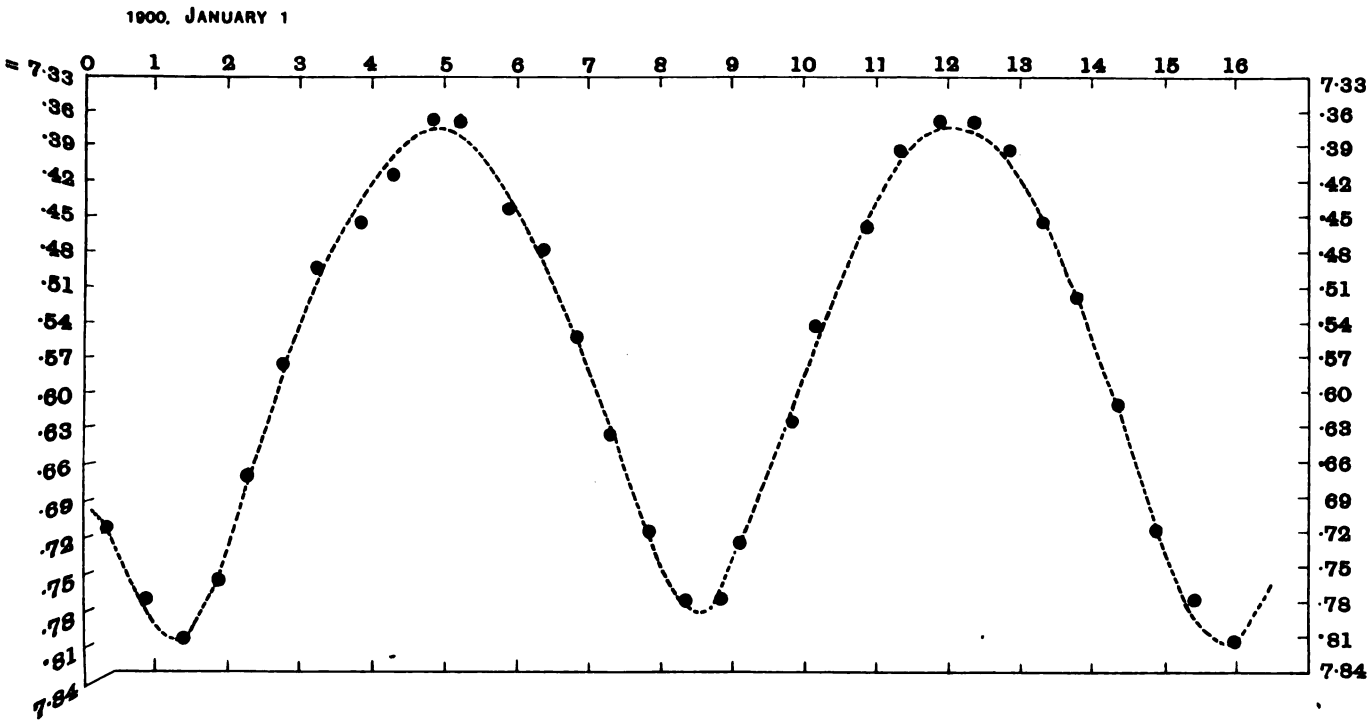
These two values are :—

$$\iota = 32^\circ{\cdot}3$$

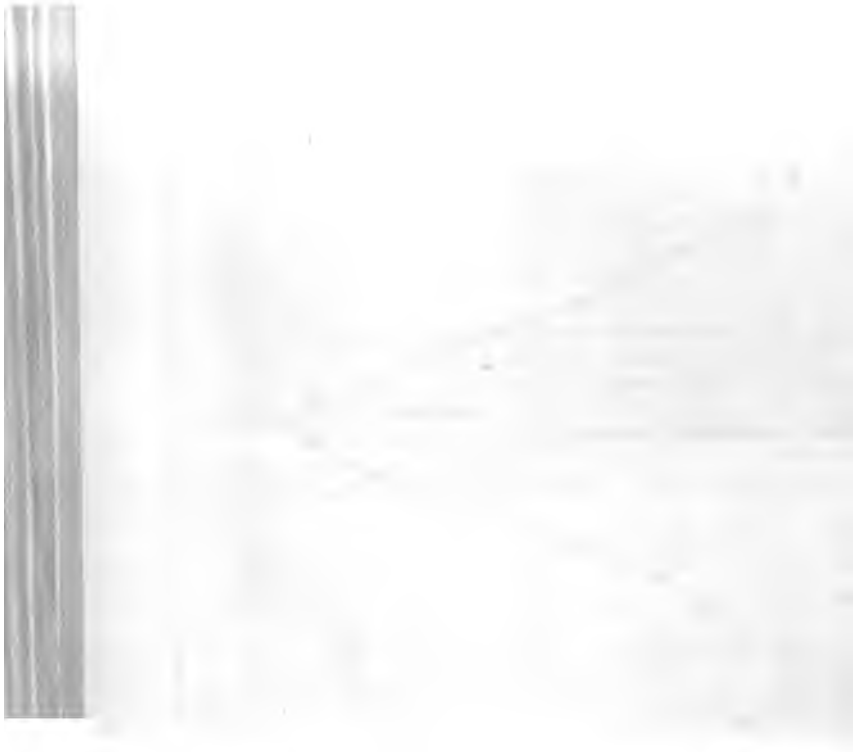
$$\epsilon^2 = 0{\cdot}65$$

FIG. 4.

LIGHT CURVE OF RR CENTAURI



Dotted line represents Theoretical Curve obtained from Element III.



Regarding, for the first approximation, the stars as equal in size, and revolving in contact, that is—

$$ac = 0.5$$
$$\lambda = 1.0$$

we readily arrive at the three remaining values L_1, L_2, and M The only data required for this determination are the values—

$$M_1 = 7^m.37$$
$$M_2 = 7^m.37$$
$$m_2 = 7^m.79$$
$$m_1 = 7^m.81$$

These yield the following :—

$$L_1 = 0.56$$
$$L_2 = 0.44$$
$$M = 7^m.37$$

Grouping now all these determinations, we have the following approximate elements as a starting point :—

$P = 14^h\ 32^m\ 10^s.76$	Elements I.
E = 1900 January $1^d\ 3^h\ 14^m$	
$e = 0.00$	
$\iota = 32.3$	
$\varepsilon = 0.81$	
$ac_1 = 0.50$	
$ac_2 = 0.50$	
$L_1 = 0.56$	
$L_2 = 0.44$	
$M = 7^m.37$	

In order to compare the accuracy of the above group of elements, theoretical magnitudes were computed from them. These computed values are set forth in columns 4 and 5 of Table VI.

The theoretical magnitudes are given in column 4, and in col. 5 the divergence, O—C, between theory and observation.

TABLE VI.

Rot. No.	Date G.M.T. h. m.	Observed Mag.	Elements I. Computed Mag.	Elements I. O−C.	Elements II. Computed Mag.	Elements II. O−C.
1	0 17	7·710	7·697	+0·013	7·693	+0·017
2	47	·770	·777	− ·007	·769	+ ·001
3	1 18	·810	·807	+ ·003	·796	+ ·014
4	47	·760	·762	− ·002	·755	+ ·005
5	2 15	·670	·683	− ·013	·679	− ·009
6	44	·570	·588	− ·018	·588	− ·018
7	3 15	·490	·496	− ·006	·500	− ·010
8	46	·450	·428	+ ·022	·434	+ ·016
9	4 16	·410	·387	+ ·023	·394	+ ·016
10	48	·370	·370	·000	·377	− ·007
11	5 14	·370	·375	− ·005	·383	− ·013
12	48	·440	·412	+ ·028	·419	+ ·021
13	6 17	·470	·466	+ ·004	·470	·000
14	47	·550	·543	+ ·007	·545	+ ·005
15	7 16	·630	·632	− ·002	·630	·000
16	49	·710	·727	− ·017	·723	− ·013
17	8 20	·770	·782	− ·012	·775	− ·005
18	48	·770	·772	− ·002	·766	·004
19	9 12	·720	·724	− ·004	·720	·000
20	46	·620	·626	− ·006	·624	− ·004
21	10 14	·540	·538	+ ·002	·540	·000
22	48	·460	·456	+ ·004	·460	+ ·000
23	11 19	·390	·401	− ·011	·408	− ·018
24	46	·370	·375	− ·005	·383	− ·013
25	12 18	·370	·370	·000	·379	− ·009
26	48	·390	·391	− ·001	·399	− ·009
27	13 17	·450	·434	+ ·016	·440	+ ·010
28	45	·510	·497	+ ·013	·501	+ ·009
29	14 19	7·610	7·598	+0·012	7·598	+0·012

Partial differential equations were formed on the basis of Elements I. by varying the various terms. These gave for the residuals in column 5 twenty-nine equations of condition, which

being dealt with in the usual manner gave as a second approximation—

$$\left.\begin{aligned} P &= 14^h\ 32^m\ 10^s{\cdot}76 \\ E &= 1900\ \text{January}\ 1^d\ 3^h\ 14^m \\ e &= 0{\cdot}00 \\ \iota &= 32^\circ{\cdot}71 \\ \varepsilon &= 0{\cdot}778 \\ ac_1 &= 0{\cdot}51 \\ ac_2 &= 0{\cdot}51 \\ L_1 &= 0{\cdot}542 \\ L_2 &= 0{\cdot}458 \\ M &= 7^m{\cdot}375 \end{aligned}\right\} \text{Elements II.}$$

A comparison between the magnitudes computed from this second set of elements and the observed magnitudes is given in columns 6 and 7 of Table VI.

In order to indicate the trustworthiness of this result, and the limitations we must place on its absolute definiteness, and also to show the character and scope of the investigation, I would desire to treat more fully the final corrections to this second set of elements.

The following variations on the several terms were made :—

$$\begin{aligned} \delta \cos^2 \iota &= +0{\cdot}022 \\ \delta \iota^2 &= +0{\cdot}055 \\ \delta ac_1 &= +0{\cdot}020 \\ \delta L_1 &= +0{\cdot}050 \\ \delta E &= +3^m{\cdot}0 \end{aligned}$$

These variations on the elements yielded twenty-nine equations of condition, corresponding to the twenty-nine mean places given in Tables V. and VI.

It may be of interest, as indicating the change produced in the light curve of a star by a small variation in the elements, to state these twenty-nine equations.

It will be at once evident, from a survey of the equations, that any attempted correction to elements roughly but reasonably obtained would be a futile labour unless the observations were of extreme accuracy. The measure of this accuracy is implied by the equations. The average departure from the mean of the observations used must be at least less than

$$0^m{\cdot}01$$

Indeed even with an accuracy of this degree of refinement, two of the corrections will always be indeterminate except in

special cases; one of these exceptional cases is when the eclipse is central. The less central the eclipse, the more the uncertainty in the determination of all the elements. For this reason the star I have chosen as an exemplification of the theory stated, *RR Centauri*, presents more difficulties in the way of an accurate determination of its elements than any other variable of this class.

I have, however, selected the star out of set purpose, and for this reason, that the determination of its elements presents grave difficulties.

We may now consider the twenty-nine equations of condition.

Equations of Condition.

$+\cdot016\,\Delta\cos^2 i + \cdot019\,\Delta e^2 + \cdot016\,\Delta ac + \cdot009\,\Delta\lambda + \cdot007\,\Delta L_1 - \cdot009\,\Delta E =$						$+0\cdot017$
·022	·023	·017	·013	·011	−·006	+ ·001
·025	·025	·017	·015	·012	·000	+ ·014
·021	·022	·017	·012	·010	+·007	+ ·005
·015	·018	·016	·009	·007	·009	− ·009
·009	·013	·014	·005	·004	·009	− ·018
·005	·008	·012	·002	·002	·008	− ·010
·002	·004	·011	·001	·001	·005	+ ·016
·001	·002	·009	·001	·001	+·003	+ ·016
·000	·001	·007	+·000	+·000	·000	− ·007
·000	·001	·007	−·000	−·000	−·002	− ·013
·001	·002	·008	·001	·000	·005	+ ·021
·004	·007	·010	·002	·002	·007	+ ·000
·007	·012	·011	·003	·003	·009	+ ·005
·011	·017	·012	·005	·005	·009	+ ·000
·017	·023	·013	·008	·008	·007	− ·013
·021	·026	·013	·011	·010	−·002	− ·005
·021	·025	·013	·011	·010	+·003	+ ·004
·017	·023	·013	·008	·008	·007	+ ·000
·011	·017	·012	·005	·005	·009	− ·004
·007	·012	·011	·003	·003	·008	+ ·000
·004	·007	·010	·002	·002	·006	+ ·000
·001	·002	·008	·001	·000	·004	− ·018
·000	·001	·007	−·000	−·000	+·002	− ·013
·000	·000	·007	+·000	+·000	−·001	− ·009
·001	·001	·009	·001	·001	·003	− ·009
·003	·004	·011	·001	·001	·006	+ ·010
·005	·008	·012	·002	·002	·008	+ ·009
$+\cdot009\,\Delta\cos^2 i + \cdot013\,\Delta e^2 + \cdot014\,\Delta ac + \cdot005\,\Delta\lambda + \cdot004\,\Delta L_1 - \cdot009\,\Delta E =$						$+0\cdot012$

Multiplying each of these equations by 1,000, to reduce the

coefficients to integers, we obtain the following normal equations :—

$+4092\,\Delta\cos^2\iota$	$+4959\,\Delta\epsilon^2$	$+3599\,\Delta ac$	$+405\,\Delta\lambda$	$+208\,\Delta L_1$	$+7\,\Delta E$	$=+416$
	$+6160$	$+4579$	$+241$	$+31$	$+8$	$=+368$
		$+4193$	$+460$	$+291$	-17	$=+227$
			$+1210$	$+1045$	$+0$	$=+460$
				911	-7	$=+387$
					$+1169$	$=-634$

An examination of the equations of condition and also of the normal equations reveal (1) that the coefficients of $\Delta\lambda$ and ΔL_1 are so similar that it is impossible to separate them. This is a fundamental relation, and arises out of the physical conditions of the problem. Its meaning is that the same change is produced in the theoretical light curve of *RR Centauri* whether we slightly vary the size of the stars, but keep the total brightness of each star the same ; or vary their relative brightness, but keep their size the same. It is fortunate that we are able from other considerations to establish a relation between the size and the brightness of binary stars. An examination of the equations of condition also reveals (2) that the observations are refined enough to respond to the call made upon them if we except the indeterminate relation existing between $\Delta\lambda$ and ΔL_1.

In solving the preceding normal equations I have thought it better to express the unknown terms as functions of $\Delta\lambda$, leaving $\Delta\lambda$ to be determined otherwise.

The solutions are :—

$$\begin{aligned}
\Delta\cos^2\iota &= +0{\cdot}284 - 0{\cdot}34\Delta\lambda \\
\Delta\epsilon^2 &= -0{\cdot}034 + 0{\cdot}20\Delta\lambda \\
\Delta ac_1 &= -0{\cdot}184 + 0{\cdot}07\Delta\lambda \\
\Delta L_1 &= +0{\cdot}420 - 1{\cdot}20\Delta\lambda \\
\Delta E &= -0{\cdot}542 + 0{\cdot}00\Delta\lambda
\end{aligned}$$

These corrections give as the final elements of *RR Centauri* :—

Elements III.

$$\begin{aligned}
P &= 14^h\,32^m\,10^s{\cdot}76 \\
E &= 1900\ \text{January}\ 1^d\,1^h\,12^m{\cdot}5\ (\text{G.M.T.}) \\
e &= 0{\cdot}000 \\
\iota &= 32^\circ{\cdot}320 - 0^\circ{\cdot}030\Delta\lambda \\
\epsilon &= 0{\cdot}776 + 0{\cdot}007\Delta\lambda \\
ac_1 &= 0{\cdot}506 + 0{\cdot}001\Delta\lambda \\
ac_2 &= 0{\cdot}506 - 0{\cdot}001\Delta\lambda \\
L_1 &= 0{\cdot}563 - 0{\cdot}060\Delta\lambda \\
L_2 &= 0{\cdot}437 + 0{\cdot}060\Delta\lambda \\
M &= 7^m{\cdot}375
\end{aligned}$$

A comparison between the magnitudes computed from these elements and observation is instituted in the last two columns of Table VI.

We may also compare the relative sufficiency of each of the three elements determined by stating the average value of the O—C discordances as found from Tables V. and VI. :—

		m
Average error :	Elements I.	0·012
	Elements II.	0·010
	Elements III.	0·009

The superior accuracy of Elements III. is evident, but it is matter of doubt whether the labour involved in working out the necessary rectifications should be undertaken with stars of the narrow range of variation $0^m{\cdot}6$ of *RR Centauri*.

We have already stated that the elements finally arrived at, Elements III., would be definitive were it possible to separate ΔL_1 and $\Delta\lambda$, but from the nature of the problem this can never be done. However refined the observations, the solution must remain undeterminate for one of these two values ; indeed to discriminate between $\Delta\lambda$ and ΔL would necessitate observations correct to within $0^m{\cdot}001$.

It remains, therefore, to consider what testimony we can make use of in arriving at some idea of the value of $\Delta\lambda$.

(1) It is evident that if the two stars are in contact, they cannot be very unequal in magnitude. But from Elements III.,

$$L_1 = 0{\cdot}563 - 0{\cdot}060\Delta\lambda$$
$$L_2 = 0{\cdot}437 + 0{\cdot}060\Delta\lambda$$

that is, under no circumstances can $\Delta\lambda$ be greater than 9.

(2) If the star S_1 be very much larger than S_2, or S_2 than S_1, it is also evident that there must be a stationary period at m_1 or m_2. Such *Algol* variables are known, and they form a distinct type. We can, from geometrical considerations, place a limit to the value of the ratio λ if there is no stationary period.

In the case where the stars move in contact

$$\lambda < \frac{\sqrt{1-\epsilon^2}+\sin\epsilon}{\sqrt{1-\epsilon^2}-\sin\epsilon}.$$

In the case where the stars are not in contact

$$\lambda < 1 + \frac{\sin\epsilon(1+e)}{r}.$$

We find therefore a major limit for $\Delta\lambda$ by either of these methods. In the present case $\Delta\lambda$ cannot be greater than 9;

hat is, for the four important elements we may state with con-idence as a margin of error :

$$\begin{aligned} i &= 32^{\circ}\cdot320 \pm 0\cdot270 \\ \epsilon &= 0\cdot776 \pm 0\cdot063 \\ ac_1 &= 0\cdot506 \pm 0\cdot009 \\ ac_2 &= 0\cdot506 \pm 0\cdot009 \end{aligned}$$

here is distinct evidence of a nexus between the twin stars in he values

$$\begin{aligned} ac_1 &= 0\cdot506 \\ ac_2 &= 0\cdot506 \end{aligned}$$

hese indicate that the two stars impinge on each other to the xtent of

$$0\cdot012$$

he radius of the orbit being taken as unity.

In order to afford facility for an inquiry into the accordance f these determinations with what the mathematical theory of he revolution of two bodies round each other, in contact, emands, we proceed to determine the density of the system.

IV. *Density of the System RR Centauri.*

In a paper on the density of close double stars, *Astrophysical urnal*, vol. x. p. 308, I set forth certain convenient formulæ the determination of the density of stars of the *Algol* type of iation.

Modifying these formulæ for stars ellipsoidal in figure, we e :

$$\text{Density of } S_1 = \frac{(0\cdot0046)^3}{ac_1{}^3(1-\epsilon^2)t^2} \cdot \frac{m_1}{m_1+m_2}$$

$$\text{Density of } S_2 = \frac{(0\cdot0046)^3}{ac_2{}^3(1-\epsilon^2)t^2} \cdot \frac{m_2}{m_1+m_2}$$

t = periodic time of star in years ;
ac_1 = semi-axis-major of S_1 ;
ac_2 = semi-axis-major of S_2 ;
m_1 = mass of S_1 ;
m_2 = mass of S_2 ;
ϵ = prolateness of figure.

ow $m_1 = m_2$, it follows that

Density of S_1 or $S_2 = 0\cdot33$

density being considered equal to unity.

This value is considerably higher than that found for the other southern *Algol* stars, and is in direct contradiction to the expectation that the nearer the members of a binary system are to one another, the more rare their physical constitution will probably be.

V. *General Conclusions.*

1. From the foregoing investigation it is evident that the determination of the prolateness of a close binary system is well within the province of exact astronomy. It is of course essential to such an investigation that the observations should be of the highest attainable accuracy.

2. It is also necessary to limit the area of the problem. Thus, in the present investigation we have assumed that the figure of a close binary system is that of two prolate spheroids whose major axes are in the same line.

This assumption is made imperative by the fact that we are dealing with relative comparisons of light, not absolute quantities; and thus the value of the axis of figure parallel to the axis of rotation must remain indeterminate.

Any combination of equations will only yield the projection of the system on a plane at right angles to the tangential plane, that is, on the plane of sight.

The equations we have adopted, and their application to the case of *RR Centauri*, or any other close binary star, do not lead to an erroneous result. They are rigorously true for two of the axes of figure, viz. the two which determine the section perpendicular to the axis of rotation.

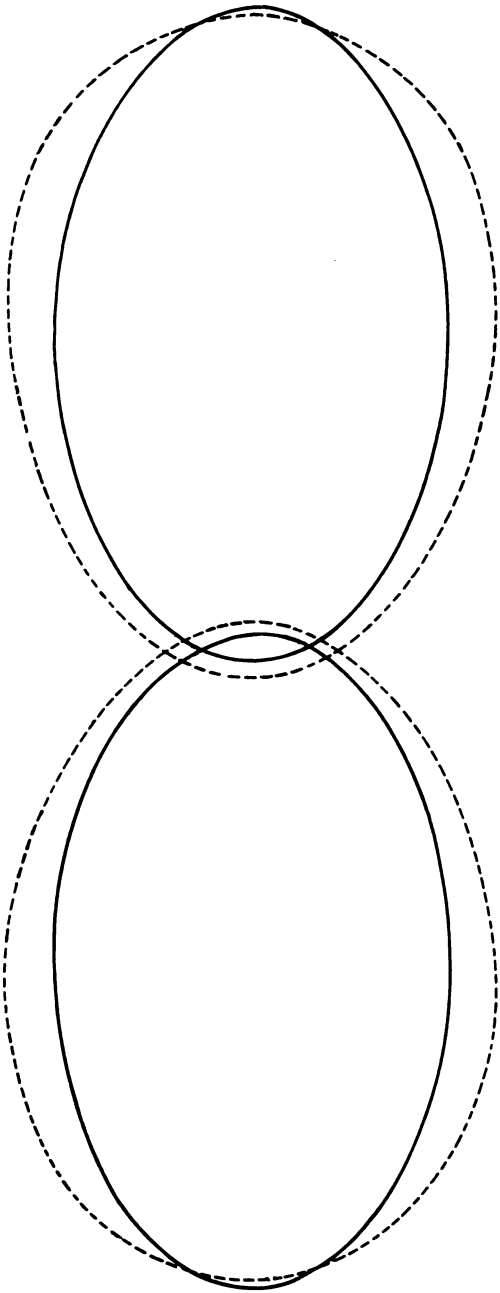
3. In this same connection it may be noted that the total amount of light which reaches us from any curved surface is the same in quantity as would be received from the projection of this surface on the tangential plane. This follows naturally from the law that the total amount of light received from each unit of surface is the amount emitted by a unit of surface into the sine of the angle of inclination of that surface.

4. We find a limitation to the rigorous determination of the problem in another direction. It is impossible to discriminate between the relative size of the stars and their relative brightness when we are considering small changes in magnitude.

Thus the same result is obtained if we consider one star to be slightly larger than the other, but its light per unit of surface slightly less; as we do if we consider the same star to be slightly smaller, but its light intensity per unit of surface somewhat greater than that of its companion.

5. Notwithstanding these limitations it is possible to discover with some measure of completeness the elements of a close binary system from the character and form of its light curve.

This has been done in the present investigation in the case of *RR Centauri*. How far the results obtained agree with what



Darwin's dumb-bell figure of equilibrium is indicated by dotted lines. The unbroken lines represent RR Centauri.

theory would demand is indicated in fig. 5 (Plate 22), where the system *RR Centauri* is delineated, and also the theoretical dumb-bell figure of equilibrium taken from Darwin's well-known charts, *Phil. Trans.* 1887, A, Plate 22, fig. 2.

6. The variable *RR Centauri* because of its inclination to the plane of sight, and consequent narrow range of variation, does not lend itself readily to investigations such as the present.

It is certain that more assured and more definite results would be, indeed have been, secured with stars moving practically at right angles to the tangent plane.

It seems to me reasonable, however, to take an example of more than ordinary difficulty as evidence of the possibility of pushing the observations of *Algol* variables to their legitimate issue.

Lovedale, S. Africa: 1903 *April.*

The National Argentine Observatory. By Dr. J. M. Thome.

(*Communicated by the Astronomer Royal.*)

During the sessions of the International Congress at the end of 1900 July the photographic zone comprised between the 23rd and 31st degrees of south declination, which had originally been assigned to the observatory of the province of Buenos Aires at La Plata, but which had lapsed on account of non-compliance, was by a unanimous vote transferred to the National Observatory of the Argentine Republic; and I at once contracted with M. Gautier, the maker of the Paris telescope, for a similar instrument, with lenses by the celebrated Henry Brothers, from discs by M. Mantois; and also a measuring machine by the same maker, a sidereal clock by Fenon, two réseaus, and various other accessories.

The boxes containing the instruments arrived in Cordoba at the beginning of 1902 January; and, the piers having been erected previously, the telescope was installed and ready for work by the end of that month; but, unfortunately, the Lumière plates, which I had ordered to be sent with the boxes containing the instruments, had been forgotten, and did not arrive before the end of April. These were then found to be 161 mm. square instead of 160 mm., and this being the extreme limit of the Gautier measuring machine they could not be used as catalogue plates, and, moreover, a large proportion of them were fogged. I had, also, when ordering our réseaus, ventured to change the present order of numbering the lines to one in which the numbering should begin with the lines which cross at the centre of the plate and increase both ways; but the maker interchanged

the legends indicating the positive and negative abscissas and ordinates, and the réseau was therefore unsuitable for the charts.

After another long delay we received a gross of plates—of the proper dimensions this time—but, most unfortunately, the réseau did not conform with the focal length of our objective, being in error by more than one millimetre in 60. With this my attempts at introducing the new réseau ended, and we had recourse to the spare one in which the lines are numbered as originally, and have used it ever since. We soon found that the plates showed varying inclinations, not being true squares; and we now always examine every plate to find the two adjacent sides which fulfil the requirements, and mark that angle before putting the plate into the holder.

The present interruptions to the work are caused almost exclusively by the Moon and bad weather. In September there was only one, in October three, and in November and December, each, two possible nights for photography. The weather has, indeed, been phenomenally bad throughout the year, there being only 173 possible nights (122 long ones) for meridian work against an average of 189 since 1890, and 270 during the first fifteen years of the existence of the Observatory. The remarkable transparency of the atmosphere has also disappeared since this region has been under irrigation, and the occasions upon which we can photograph 11th magnitude stars with 6^m exposures, owing to their inconstant light, are very rare; we generally give from 7^m to 8^m, and even 10^m, upon dull nights. After midnight there are frequently heavy dews which interrupt the work; and, upon some occasions, after a day of high winds and dust, we have found the lenses entirely covered with a fine dust at the end of the night, although nothing unusual was perceptible to the senses, and the nights were perfectly calm and apparently good ones.

Of the 208 plates, mainly short exposures, which we have obtained up to the beginning of April, 196 seem to fulfil the requirements, and of these a considerable number will, no doubt, show stars of the 12th magnitude owing to the uncertainty as to the proper length of exposure. The supposition is based upon the number of stars in our DM. for those regions. I think it will be found that that catalogue contains all the stars to the 10·5 magnitude upon Pickering's scale, and there are undoubtedly some in all the plate regions as faint as, or fainter than, the 11th magnitude, especially in the regions outside the Milky Way. In these regions probably everything to the $10\frac{1}{4}$ magnitude has been recorded—certainly upon the best nights.

I received from the Repsolds in September a Gill measuring machine, which is now also in use. After it had been mounted and adjusted according to Sir David's instructions I noticed a defect in the ratchet motion that carries the plate under the microscope, which threw it out of adjustment whenever the

motion was reversed by as much as the width of the double wires. I could find no one in Cordoba who was able to correct it, but finally, after a delay of some months, found an instrument maker in Buenos Aires who was able to counteract the rocking motion mechanically without altering any original part, and it now has a uniform and consistent performance in both direct and reverse motions. It affords a rapid, precise, and elegant means of determining the rectangular coordinates.

The reference stars in 23°, 24°, and 25°, from 12 to 15 upon each plate, selected from our DM., have now been observed, at least twice, in each position, circle east and circle west, of the meridian instrument. In the meanwhile I contracted with Bamberg of Berlin for a registering micrometer with clockwork attachment, which will shortly arrive, and I now propose to observe the same stars once more in position circle west. The advantage of being able to bisect an apparently stationary object, no matter what its declination or size of disc, and to record the bisection times upon a chronographic sheet, seems to me very great as compared with the present "chronographic" and "eye-and-ear" transits. I have also increased the dimensions of our meridian room, which was only 3·7 metres long, 4 wide, and 3·1 high, to 16·5 long and 3·6 high. The room now includes the collimator piers and all accessory instruments, clock, chronometers, reversing chair, &c.; and when the new micrometer arrives I confidently hope to improve upon the previous observations of these stars. The number of observations already made is nearly 26,000, and the probable error in the final positions will be about 0″·3.

The reobservations, made in former years, of all the DM. stars to the 9·3 magnitude in the region included between 22 and 37 degrees are still under revision. From a comparison with the positions given by Boss in *A. J.* Nos. 531–532, the probable error of our determinations seems to be ±0″·4.

The DM. zone included between 52° and 62° is under revision—for magnitudes principally. I have adopted Pickering's photometric scale definitely because it seems to me, after long trial, to be essentially correct; and his catalogue gives besides convenient reference belts throughout our sky. I cannot agree with Newcomb that it would have been better to continue the scale used in vols. xvi. and xvii., even supposing that I could have adhered to it consistently, which, as it was not homogeneous, would hardly have been possible. It is besides easy to reduce those magnitudes to the photometric scale, and I have given the approximate corrections in the preface to vol. xviii. p. xx. The reason why I did not estimate to tenths, or even quarter-magnitudes, while observing the stars below 10^{m} will become perfectly evident to anyone who attempts it with such means as I have; that was, moreover, supposed to be our lowest limit. In the present revision, however, I have done this in part, although it necessitates a great deal of additional work; but it will be

useful in determining what our lowest limit has really been, and as an indication that the photographic scale can be brought into good accord with the photometric, since the Cordoba and Cape scales agree, for certain plates, throughout the entire range.

The disadvantage under which I labour, in the fact that it is almost impossible to find permanent and reliable assistance here, is very great. I have had many untrustworthy men in my employ; and, in general, the foreigners who come here are true adventurers, who are not to be restrained when a prospect of better remuneration or less work offers; and their substitutes are usually drawn from the same uncertain element. This was not the case during the first period of our existence, when the remuneration was essentially upon a gold basis.

Catalogue of Right Ascensions of 76 Stars. By Robert Snow.

[The following catalogues were presented to the Society many years ago, but were not at the time considered worthy of publication. Dr. Ristenpart, who has undertaken the great work of combining all existing catalogues, on seeing the notes in *Monthly Notices*, iii. p. 99, and iv. p. 143, wrote to ask if these catalogues were still in existence. Search was made in the archives of the Society, and Mr. Snow's catalogues were found and sent (by permission of the Council) to Dr. Ristenpart. In returning them he expressed an opinion in favour of their publication; and the Council on receipt of this valuable opinion directed that the catalogues should be printed in the next following number of the *Monthly Notices*. In preparing them for publication the Editors have omitted from the first Catalogue a column of "extreme differences," and from the second a column of "greatest difference from the mean." Nos. 7 and 34 in the second Catalogue have been bracketed, as they were made with a 20-inch transit. One or two corrections have been pointed out by Dr. Ristenpart: thus the A.S.C. Nos. of 55 and 69 in the second Catalogue are given in the MS. as 1316 and 1609, and the B.A.C. number for No. 17 has been supplied. At the end of each catalogue will be found a list of corrections to the comparisons with other catalogues. It seemed desirable to give these instead of altering the text, as they are the only indication we now have of the general accuracy of the work.]

EDITORS of the *Monthly Notices*.

This catalogue was constructed with a view towards determining how nearly the results of a small instrument, used under disadvantageous circumstances, would approach to those obtained at a first-rate observatory. The instrument employed was a 20-inch transit, mounted upon the usual cast-iron stand, fixed

upon a pier of brickwork, in connexion with a chronometer showing sidereal time and beating half-seconds. The transits were, if possible, always observed over the seven wires, and when by accident, or by the intervention of clouds, the passages over any of them were lost, the remaining wires were reduced individually to the mean of all the seven by the help of a table of the equatorial distances of each wire from the mean of the whole. This table was obtained from ten complete transits of *Polaris* and twenty of δ *Ursæ Minoris*, a correction having been applied for the circular path of *Polaris*.

Numerical corrections for instrumental error have been used (viz. for the errors of inclination, collimation, and deviation in az.) in preference to attempting to destroy them by mechanical means; and in applying these corrections much trouble has been avoided by the use of Mr. Epps's tables. No correction has been applied for the inequality of the pivots.

With respect to the instrument's optical power, stars of the fourth and fifth magnitude have been considered as more agreeable to observe than brighter stars, and no difficulty has been found, on fine nights, in observing stars of the seventh magnitude. An eighth magnitude will but just allow of sufficient illumination to render the wires perceptible, and cannot be observed with any certainty; a star following β *Canis Minoris* about 42^s was found to be a good specimen of the *minimum visibile* with such an instrument in a perfectly dark field.

In observing the transits a second was taken from the chronometer when a star was approaching the first wire; and the habit of never looking again at the chronometer until the star had passed over all the wires was soon acquired. The *half-beat* of the chronometer was merely mentally acknowledged without further account being taken of it; and in this way observing with a half-seconds chronometer became a similar operation to observing with a regular transit clock. Indeed, a clock and the chronometer in question have been used on the same evening without any sense of confusion arising from the change. The stars whose places are given in the *N.A.* were used for determining the clock errors, with the exception of *Polaris* and δ *Ursæ Minoris*, whose places were taken from the Berlin Ephemeris until the appearance of the *N.A.* for 1834.

Some few additional stars have been taken for this purpose from the Greenwich Catalogue of 1112 stars [1830] during the course of last year; but it has been done but seldom. As far as possible each unknown star has been made to depend on one or more of the standard stars situated nearly in the same parallel of declination. The power used, both with and without the diagonal eyepiece, was 54; the diagonal eyepiece was laid aside whenever it was possible to do so. Of course an instrument so humble as the one in question must always be liable to great instability, which no care in using it will prevent; besides which the employment of the diagonal eyepiece is very unsatis-

factory owing to the awkward position into which the use of it forces the head in observing stars in and near the zenith, not to mention the loss of light and the additional handling of the instrument which it occasions.

The places of 67 out of the 76 stars which this catalogue consists of are to be found in the Greenwich Catalogue of 1112 stars. Five out of the 67 are in absolute agreement with the Greenwich places, and there are 41 stars whose differences from Greenwich lie between $0^s{\cdot}00$ and $0^s{\cdot}10$; 17 whose differences lie between $0^s{\cdot}10$ and $0^s{\cdot}20$, and 4 whose differences are above $0^s{\cdot}20$, the widest difference being $0^s{\cdot}26$. Amongst these 62 differences the + and the − signs are exactly equally divided, and the sum of the 31+ differences is $2^s{\cdot}95$, and of the 31 − differences is $3^s{\cdot}03$; and the difference of these two quantities is $-0^s{\cdot}08$, which divided by 67 (which is the number of the stars under comparison) gives $-0^s{\cdot}0012$ for the final *mean* difference of the present catalogue from that of Greenwich.

ROBERT SNOW.

September 30, 1834.

(13 *St. James's Place.*)

Ref. No.		Name of Star.	Mean R.A. 1835. h	m	s	No. of Obs. E	W	Precession. s	Diff. from Gr. 1112 Stars. s	Diff. from A.S.C. s
1	B	Piscium	0	6	28·74	5	0	+3·073	...	−0·06
2	*d*	Piscium	0	12	6·76	6	4	+3·077	+0·10	+0·31
3	58	Piscium	0	38	25·57	3	4	+3·111	...	−0·95
4	*e*	Piscium	0	54	23·35	5	5	+3·106	−0·06	−0·53
5	ζ'	Piscium (pr^s star)	1	5	7·03	6	4	+3·112	+0·12	+0·06
6	μ	Piscium	1	21	32·79	5	5	+3·111	0·00	−0·37
7	ν	Piscium	1	32	51·06	3	7	+3·111	+0·10	−0·23
8	ξ'	Ceti	2	4	15·76	3	4	+3·165	−0·07	+0·57
9	ν	Ceti	2	27	13·34	5	5	+3·136	−0·06	−0·40
10	μ	Ceti	2	36	1·79	5	5	+3·207	+0·10	−0·51
11	λ	Ceti	2	50	52·78	6	4	+3·199	...	−0·62
12	*q*	Orionis	4	40	53·33	5	7	+3·251	+0·04	+0·21
13	*e*	Aurigæ	4	50	8·66	7	3	+4·280	−0·09	−0·50
14	η	Aurigæ	4	54	57·28	5	5	+4·182	+0·06	−0·26
15	μ	Orionis	5	53	18·42	5	5	+3·295	+0·04	−0·69
16	ν	Orionis	5	58	8·93	5	5	+3·421	+0·17	−0·22
17	κ	Aurigæ	6	4	51·67	5	5	+3·825	+0·20	−0·54
18	811	−A.S.C. (foll^g star)	6	22	40·71	6	4	+3·497	...	+0·12
19	β	Canis Minoris	7	18	12·17	12	10	+3·259	−0·18	−0·66
20	ζ	Cancri	8	2	44·61	5	5	+3·445	...	−0·33
21	β	Cancri	8	7	33·79	6	5	+3·262	−0·01	−0·44
22	δ	Hydræ	8	28	55·16	4	6	+3·185	−0·13	−0·61

Ref. No.		Name of Star.	Mean R.A. 1835. h	m	s	No. of Obs. E	W	Precession. s	Diff. from Gr. 1112 Stars. s	Diff. from A.S.C. s
23	γ	Cancri	8	33	43·62	1	4	+3·493	+0·02	−0·32
24	δ	Cancri	8	35	18·06	4	6	+3·422	−0·09	−0·44
25	ε	Hydræ	8	38	2·26	4	6	+3·195	−0·13	−0·43
26	ρ	Hydræ	8	39	41·37	3	7	+3·184	−0·04	−0·32
27	ζ	Hydræ	8	46	40·32	6	6	+3·183	−0·25	+0·19
28	κ	Cancri	8	58	48·34	3	7	+3·259	−0·18	+0·25
29	π	Leonis	9	51	29·43	5	5	+3·179	0·00	−0·22
30	ρ	Leonis	10	24	7·07	9	4	+3·166	+0·04	−0·02
31	l	Leonis Minoris	10	29	24·99	6	5	+3·401	+0·07	−0·21
32	m	Leonis Minoris	10	36	40·38	5	5	+3·361	+0·10	−0·66
33	o	Leonis Minoris	10	44	3·77	6	4	+3·375	−0·07	−0·20
34	σ	Leonis	11	12	37·66	6	5	+3·102	0·00	−0·48
35	ι	Leonis	11	15	19·26	6	4	+3·121	−0·14	−0·52
36	ν	Virginis	11	37	22·82	4	6	+3·086	−0·13	−0·34
37	o	Virginis	11	56	48·39	4	7	+3·071	−0·17	−0·33
38	α	Comæ Berenices	12	18	43·74	2	3	+3·011	+0·09	−0·58
39	d	Canum Venat.	12	25	53·49	2	4	+2·864	0·00	−0·06
40	ρ	Virginis	12	33	32·02	5	5	+3·030	−0·24	−0·63
41	ε	Virginis	12	53	57·96	6	4	+3·003	+0·06	−0·19
42	τ	Boötis	13	39	25·49	4	6	+2·883	−0·03	−0·55
43	η	Boötis	13	46	49·69	5	5	+2·859	+0·15	−0·21
44	ρ	Boötis	14	24	43·08	6	4	+2·592	−0·03	−0·02
45	ξ	Boötis	14	43	46·74	5	5	+2·753	+0·07	−0·27
46	β	Boötis	14	55	43·95	2	8	+2·261	−0·05	−0·43
47	μ	Boötis	15	18	15·44	4	6	+2·275	+0·11	−0·41
48	β	Coronæ Boreal.	15	21	1·71	5	5	+2·483	−0·08	−0·05
49	β	Serpentis	15	38	34·44	6	4	+2·757	+0·05	−0·28
50	ε	Serpentis	15	42	35·75	6	5	+2·972	−0·06	−0·19
51	γ	Serpentis	15	48	50·09	5	5	+2·741	+0·03	−0·08
52	h	Herculis	16	5	5·81	4	6	+2·956	...	−0·04
53	β	Herculis	16	23	7·71	5	5	+2·579	+0·03	−0·55
54	ι	Ophiuchi	16	46	12·26	5	5	+2·834	−0·08	−0·19
55	κ	Ophiuchi	16	49	51·78	5	5	+2·852	+0·10	−0·18
56	ε	Herculis	16	53	58·61	3	2	+2·293	+0·15	−0·34
57	δ	Herculis	17	8	15·41	2	3	+2·460	−0·01	−0·97
58	β	Ophiuchi	17	35	19·52	4	6	+2·960	−0·08	−0·30
59	S^2	Ophiuchi	17	59	31·80	8	2	+2·843	+0·03	−0·43
60	ε	Aquilæ	18	52	8·19	6	4	+2·723	−0·03	−0·82

Ref. No.		Name of Star.	Mean R.A. 1835. h	m	s	No. of Obs. E	W	Precession. s	Diff. from Gr. 1112 Stars. s	Diff. from A.S.C. s
61	A	Aquilæ	19	11	57·44	6	4	+2·796	...	+0·18
62	*b*	Aquilæ	19	17	6·14	6	4	+2·871	+0·09	−0·34
63	μ	Aquilæ	19	26	1·57	7	3	+2·915	+0·10	−0·31
64	σ	Aquilæ	19	31	3·07	6	4	+2·960	+0·01	+0·34
65	τ	Aquilæ	19	56	4·73	5	5	+2·929	...	−0·19
66	ϵ	Delphini	20	25	19·79	2	3	+2·864	0·00	−0·34
67	β	Delphini	20	29	48·59	2	3	+2·803	+0·20	−0·30
68	γ	Equulei	21	2	19·00	5	5	+2·912	+0·05	−0·17
69	*a*	Equulei	21	7	34·34	5	4	+2·995	+0·26	−0·05
70	T'	Pegasi	21	30	16·12	4	2	+2·997	−0·15	−0·38
71	θ	Pegasi	22	1	52·70	4	5	+3·006	−0·21	−0·05
72	ξ	Pegasi	22	38	27·24	4	6	+2·975	−0·17	−0·35
73	*l*	Pegasi	22	58	41·82	2	5	+3·015	...	−0·19
74	*q*	Pegasi	23	20	48·90	3	5	+3·020	...	−0·44
75	O	Pegasi	23	34	58·81	3	5	+3·044	...	−0·40
76	ω	Piscium	23	50	50·56	6	4	+3·062	−0·04	−0·02

Note.—The following corrections should be made in the columns giving comparisons with Pond's Catalogue and the Catalogue of the Astronomical Society.—Eds. *M.N.*

			s				s
No. 1.	Difference from	A.S.C.	+0·07	No. 30.	Difference from	A.S.C.	−0·10
4.	,,	,,	−0·03	61.	,,	,, ,,	+0·15
7.	,,	,,	−0·13	67.	,,	,, Gr. 1112	−0·20
8	,,	,,	−0·43	69.	,,	,, A.S.C.	−0·08
28.	,,	,,	+0·65	71.	,,	,, Gr. 1112	−0·21

Catalogue of Right Ascensions of 125 *Stars.* By Robert Snow.

The accompanying right ascensions were observed with a transit instrument of $3\frac{1}{2}$ feet focal length and aperture $2\frac{3}{4}$ inches, made by Mr. Simms.

It has seven vertical spider's lines in its principal focus, the mean equatorial interval of which is $11^s{\cdot}81$, and has an additional vertical wire movable in a direction parallel to the rest by means of a micrometer screw, one revolution of which corresponds to three seconds of time at the equator. The instrument is mounted on stone pillars let into a thick flag-stone fixed on a brick pier worked up in cement resting on a foundation of hard flinty gravel. It is very easily reversed on its Y's,

and possesses optical power sufficient to allow of observing *Polaris* or *γ Draconis* when on the meridian with the Sun. The usual observing power is 130. The view is uninterrupted from the northern to the southern horizon. Numerical corrections have been applied to the observations for instrumental error, and tables for the purpose formed for the known and for the catalogue stars, agreeably to Mr. Epps's paper on the subject.

The instrument, from its situation and construction, has been found to be stable to a degree that is very satisfactory, but not without perceptible alterations from time to time, both in level and azimuth. The level error has of late been kept small by making occasional use of the adjusting screws, the proper numerical correction being afterwards applied to the remaining error. The collimation of the middle wire was in the first instance adjusted, and is occasionally examined, by referring it, with the assistance of the micrometer wire, to a meridian mark distant about three-quarters of a mile; and for a like purpose by night a tolerably well-defined artificial star has been formed by a bright reflecting lamp, at the same distance, shining through a circular aperture of half an inch. The error of collimation of the mean of the seven wires has been found by observing groups of known stars in reversed positions of the instrument, and comparing the clock errors so obtained.

The azimuthal adjusting screws have been rarely touched; the error, however, has never been inconveniently large, and has also had a numerical correction applied to it. This error has been found from consecutive transits of *Polaris*, and by combining *Polaris* with another known star, generally to the south of the equator; λ and δ *Ursæ Min.* have also both been similarly made use of, but much less frequently. A specimen of the printed forms made use of for registering the observations is subjoined. They have the disadvantage of rendering the observation books rather voluminous, but present great advantages in their neatness and regularity, and the ease with which they are referred to when necessity for after-discussion arises.

Polaris having been observed ten times over all the wires, the difference of the times of passing each wire from the mean of the whole was found and reduced to the equator, care having been taken to correct for the curved path of the star when at a distance from the middle wire. Thus a ready means of reducing all or any of the wires severally to the mean of the seven is obtained for stars anywhere situated, and is always resorted to in the case of a broken observation. No one wire is considered more valuable than another.

The 100 principal stars of the N.A. were employed for obtaining the clock errors, and with very few exceptions, each observation of a catalogue star is governed by a clock error derived from a mean of from three to six or eight known stars. The transit clock is a new one by Molyneux, and has the usual dead-beat escapement and mercurial pendulum.

The latitude of the place has been before stated to be 51° 15′ 58″ north, from a mean of twenty observations of stars on the prime vertical, made with a small transit instrument turned east and west. The difference of longitude between it and Mr. Wrottesley's observatory has been found by transporting between the two places a pocket mean-time chronometer by Baird belonging to Mr. Wrottesley, two box chronometers by Molyneux going mean time, and a box chronometer by Molyneux going sidereal time.

The comparisons of the chronometers with the two transit clocks were made as follows. On Thursday (May 26, 1836) at Blackheath and at Ashurst; on Saturday (May 28) at Ashurst, and at Blackheath and again at Ashurst; on Monday (May 30) at Ashurst and at Blackheath. The comparisons of the clocks and chronometers and the observations of stars determining the clock errors at both places were made by the same person. It will be sufficient to give the differences of longitude as obtained from the four chronometers and the four journeys severally, using the mean rate of each chronometer for five days.

Thursday.	m	s
No. 1055	1	12·32
No. 1119	1	12·00
No. 1115	1	12·64
Baird ...	1	13·39
Mean ...	1	12·34

Saturday Morning.	m	s
No. 1055	1	13·02
No. 1119	1	13·35
No. 1115	1	12·47
Baird ...	1	13·23
Mean ...	1	13·02

Saturday Evening.	m	s
No. 1055	1	12·79
No. 1119	1	12·68
No. 1115	1	13·26
Baird ...	1	11·87
Mean ...	1	12·63

Monday.	m	s
No. 1055	1	13·09
No. 1119	1	13·88
No. 1115	1	13·16
Baird ...	1	13·76
Mean ...	1	13·47

Final Mean.	m	s
No. 1055	1	12·34
No. 1119	1	13·02
No. 1115	1	12·63
Baird ...	1	13·47
Mean ...	1	12·86

But on Saturday the four chronometers were carried both to and from the two places; using, therefore, only the comparisons of Saturday and the proportional parts of the rates of the chronometers for that day, the four following differences of longitude are obtained:

Saturday.	m	s
No. 1055	1	12·78
No. 1119	1	13·04
No. 1115	1	12·59
Baird ...	1	12·59
Mean ...	1	12·75

On the whole the difference of longitude between the two places may be fairly stated at $1^m\ 12^s{\cdot}8$, Ashurst, west of Blackheath.

	No in A.S.C.	Star.	Mag.	R.A. Jan. 1, 1830. h m s	Precession. s	No. of Obs.	Greater than A.S.C. s	Greater than Wrottesley. s
1	19	Piscium	6·7	0 9 4·01	+3·069	2	+0·26	−0·09
2	28	*t* Piscium	6	0 16 41·46	+3·070	2	+0·41	0·00
3	35	28 Andromedæ	6	0 21 9·74	+3·136	1	+0·06	−0·40
4	47	Piscium	7	0 25 22·53	+3·092	2	+0·23	−0·01
5	82	*y* Piscium	5·6	0 40 3·41	+3·135	2	+0·19	...
6	108	ψ' Piscium	5·6	0 56 34·80	+3·191	2	−0·13	...
* [7	183	Piscium	7	1 31 38·15	+3·140	3	+0·49	−0·07]
8	212	Piscium	7	1 50 20·46	+3·194	3	+0·35	−0·01
9	398	F^1 Tauri	6·7	3 32 31·48	+3·439	1	+0·35	+0·09
10	401	F^2 Tauri	7	3 33 58·13	+3·440	1	+0·43	−0·02
11	422	Tauri	7	3 39 56·25	+3·504	2	+0·19	+0·03
12	429	Tauri	6	3 43 27·41	+3·402	2	+0·81	−0·03
13	593	Tauri	5·6	4 57 45·24	+3·541	3	+0·46	...
14	594	Tauri	6	4 57 45·50	+3·642	3	+0·21	−0·07
15	609	y^3 Orionis	6·7	5 1 56·07	+3·435	3	+0·36	−0·06
16	634	22 Aurigæ	7	5 12 37·20	+3·786	4	+0·30	+0·02
* 17	...	[B.A.C. 1657]	...	5 12 51·47	+3·057	4	...	...
18	635	*o'* Orionis	5·6	5 13 5·40	+3·055	5	+0·77	...
19	636	Aurigæ	7	5 13 41·36	+3·856	2	+0·15	−0·05
* 20	637	Aurigæ	7	5 13 41·59	+3·854	3	+0·07	−0·06
21	716	P Tauri	5·6	5 40 0·15	+3·365	3	+0·74	...
22	726	56 Orionis	5·6	5 43 36·95	+3·110	7	+0·13	...
* 23	743	Aurigæ	7	5 50 19·50	+3·765	6	+0·13	−0·04
24	748	χ^3 Orionis	5·6	5 53 23·68	+3·546	4	+0·17	...
25	755	Orionis	7	5 56 56·19	+3·440	5	+0·20	+0·01
26	762	4 Geminorum	7	6 0 11·10	+3·639	5	+0·43	−0·04
* 27	779	8 Geminorum	7	6 5 55·98	+3·663	5	+0·59	−0·17
28	792	Geminorum	7	6 14 15·43	+3·649	3	+0·22	+0·14
* 29	805	[B.D. 20°, 1442]	9·1	6 19 3·10	+3·588	1	+1·16	−0·67
30	825	25 Geminorum	7	6 30 37·96	+3·782	3	+0·68	+0·14

	No. in A.S.C.	Star.	Mag.	R.A. Jan. 1, 1830. h m s	Precession. s	No. of Obs.	Greater than A.S.C. s	Greater than Wrottesley. s
31	865	Geminorum	7	6 50 4·60	+3·446	3	+0·30	−0·01
32	889	*n* Geminorum	7	7 4 17·80	+3·671	3	+0·33	−0·04
* 33	908	58 Geminorum	7	7 13 14·90	+3·613	4	+0·85	+0·20
* [34	917	*β* Canis Min.	3	7 17 55·88	+3·259	22	+0·67	...]
35	919	*b'* Geminorum	5·6	7 18 44·45	+3·750	3	+0·57	...
36	934	Geminorum	7	7 27 5·46	+3·533	3	+0·44	−0·06
37	939	Geminorum	7	7 29 1·14	+3·853	3	...	+0·09
38	956	B Geminorum	7	7 38 23·27	+3·598	3	+0·68	+0·20]
39	967	*l* Geminorum	6·7	7 45 44·26	+3·511	3	+0·20	+0·21
40	975	Cancri	7	7 50 5·34	+3·357	3	+0·14	+0·14
41	1004	Cancri	7	8 4 26·68	+3·444	3	+0·11	+0·07
42	1080	Cancri	7	8 41 1·97	+3·412	3	+0·26	+0·19
43	1108	78 Cancri	7	8 59 30·01	+3·379	3	+0·74	+0·26
44	1119	K' Hydræ	6	9 4 2·39	+2·964	3	+0·71	+0·08
45	1128	Leonis	7	9 8 37·52	+3·265	3	+0·40	−0·01
* 46	1132	Leonis	7	9 11 15·27	+3·523	3	−1·77	...
47	1173	Leonis	7	9 33 50·74	+3·373	3	+0·62	+0·21
48	1180	20 Leonis	7	9 40 18·52	+3·377	5	+0·27	+0·25
49	1198	Leonis	6·7	9 53 19·43	+3·362	3	+0·18	+0·15
50	1202	Leonis	7	9 56 26·97	+3·272	4	+0·24	+0·17
51	1217	Leonis	7	10 5 7·53	+3·328	3	−0·04	+0·08
52	1239	*i* Sextantis	6	10 17 56·09	+3·067	3	+0·10	+0·09
53	1246	K Sextantis	6	10 20 50·73	+3·050	3	+0·51	+0·08
54	1263	50 Leonis	6·7	10 29 46·96	+3·225	3	+0·15	+0·13
55	1316	*p*4 Leonis	7	11 0 32·96	+3·066	5	+0·23	+0·12
* 56	1336	Leonis	7	11 14 35·79	+3·073	4	+0·23	+0·22
57	1348	Leonis	7	11 19 12·52	+3·065	2	+0·03	+0·01
58	1364	Virginis	7	11 29 43·21	+3·063	4	+0·49	+0·18
59	1383	Virginis	7	11 49 31·23	+3·073	5	+0·33	+0·25
60	1385	*b* Virginis	5·6	11 51 14·61	+3·072	2	+0·27	...
61	1399	*s* Virginis	7	12 1 23·49	+3·067	5	+0·29	+0·16
62	1459	Virginis	6·7	12 29 59·18	+3·079	3	−0·07	+0·13
63	1518	Virginis	7	13 5 18·18	+3·053	3	+0·12	+0·18
64	1538	*w* Virginis	5·6	13 20 6·76	+2·948	3	+0·14	...
65	1540	Virginis	7	13 20 31·59	+3·072	2	−0·06	0·00

	No. in A.S.O.		Star.	Mag.	R.A. Jan. 1, 1830. h m s	Precession. s	No. of Obs.	Greater than A.S.O. s	Greater than Wrottesley. s
* 66	1548	77	Virginis	7	13 24 32·33	+3·125	3	+0·24	+0·18
67	1551	l^3	Virginis	6	13 26 41·08	+3·107	6	+0·13	+0·03
68	1561		Virginis	7	13 36 2·76	+3·133	10	+0·13	+0·11
69	1601		Virginis	7	13 55 21·98	+3·164	5	+0·12	+0·04
70	1638	N^1	Virginis	6·7	14 18 29·49	+3·139	3	+0·40	+0·06
* 71	1651		Libræ	6·7	14 27 57·38	+3·233	5	−2·21	−0·63
* 72	1709		Libræ	7	14 56 21·10	+3·456	3	+0·41	+0·14
73	1721	i^1	Libræ	5·6	15 2 32·90	+3·400	3	−0·04	...
74	1723	i^2	Libræ	6·7	15 3 38·95	+3·399	3	−0·06	−0·05
75	1725	τ	Libræ	7	15 4 59·08	+3·365	3	+0·15	+0·10
* 76	1752		Libræ	7	15 20 35·86	+3·375	1	+1·26	+0·70
77	1758		Libræ	6·7	15 22 51·63	+3·426	6	+0·13	−0·01
78	1850	c^2	Scorpii	5	16 1 50·91	+3·673	1	−0·54	...
79	1857	χ	Scorpii	6	16 4 27·21	+3·304	5	+0·02	−0·04
80	1865		Ophiuchi	6	16 7 59·28	+3·141	3	...	+0·09
* 81	1918	g	Draconis	5	16 39 46·06	+0·387	5	+1·09	...
82	1924		Scorpii	6·7	16 43 23·60	+3·531	3	+0·07	+0·05
83	1937		Scorpii	6·7	16 47 5·13	+3·512	3	+0·13	−0·05
84	1938	54	Herculis	5·6	16 47 54·04	+2·638	5	+0·05	...
85	1953	32	Ophiuchi	5·6	16 55 20·67	+2·740	5	+0·21	...
86	1989	70	Herculis	5·6	17 13 54·10	+2·467	5	+0·27	...
* 87	1990		Scorpii	6	17 14 32·70	+3·578	3	+0·45	+0·38
88	2004		Ophiuchi	6	17 20 9·49	+3·057	3	+0·07	−0·11
89	2223		Sagittarii	7	19 2 14·70	+3·410	1	+0·07	−0·10
90	2250	ρ^2	Sagittarii	5·6	19 11 56·47	+3·496	1	+0·05	...
91	2256	χ^1	Sagittarii	6	19 14 55·64	+3·654	1	+0·17	+0·24
92	2259	3	Vulpeculæ	6	19 15 53·00	+2·453	1	+0·35	−0·11
93	2310		Sagittarii	6	19 33 51·62	+3·416	4	+0·60	+0·11
94	2345		Sagittarii	7	19 49 29·27	+3·564	1	+0·27	0·00
95	2353	χ	Sagittæ	6	19 52 22·72	+2·706	2	+0·07	+0·05
* 96	2363	τ	Aquilæ	5·6	19 55 50·13	+2·929	1	+0·21	...
97	2370	i	Vulpeculæ	5·6	19 59 35·12	+2·573	2	−0·29	...
98	2373	ξ^1	Capricorni	6·7	20 2 31·99	+3·331	1	+0·20	−0·33
99	2375	ξ^2	Capricorni	6	20 2 57·13	+3·335	1	+0·21	+0·21
100	2383	l	Vulpeculæ	5·6	20 7 15·60	+2·460	2	+0·19	...

	No. in A.S.C.		Star.	Mag.	R.A. Jan. 1, 1830. h m s	Precession. s	No. of Obs.	Greater than A.S.C. s	Greater than Wrottesley. s
101	2431	ρ	Vulpeculæ	5·6	20 29 49·42	+2·554	4	0·00	...
102	2456	13	Delphini	5·6	20 39 23·01	+2·971	5	−0·06	...
103	2495	λ	Equulei	6	20 53 49·62	+2·957	2	−0·01	+0·08
104	2504	A	Capricorni	5·6	20 57 10·69	+3·528	3	+0·40	...
105	2529		Aquarii	7	21 12 50·82	+3·226	1	−0·01	+0·02
106	2531	y^1	Aquarii	6	21 13 49·39	+3·225	1	+0·01	+0·22
107	2535	β	Equulei	5·6	21 14 27·29	+2·974	2	+0·23	...
108	2564	5	Pegasi	5·6	21 29 48·32	+2·795	2	+0·64	...
109	2589	11	Pegasi	5·6	21 38 36·62	+3·042	3	+0·69	...
110	2599		Aquarii	7	21 43 52·85	+3·131	1	+0·30	−0·02
111	2603	B	Pegasi	5·6	21 45 19·84	+2·721	2	+0·14	...
112	2612	20	Pegasi	5·6	21 52 48·70	+2·914	3	+0·51	...
113	2642	ϕ	Piscis Austr.	5·6	22 4 10·52	+3·384	3	+0·62	...
114	2666	C	Pegasi	5·6	22 13 28·53	+2·757	3	+0·10	...
115	2682	H^2	Pegasi	5·6	22 19 15·19	+3·030	2	+0·56	...
116	2686	f	Aquarii	6	22 21 10·74	+3·222	1	+0·81	−0·52
117	2723	g^2	Aquarii	6	22 38 24·61	+3·242	1	+0·17	0·00
118	2731	σ	Pegasi	5·6	22 43 47·54	+2·999	5	+0·51	...
119	2732	K	Aquarii	6	22 44 31·02	+3·164	1	+0·26	−0·21
120	2738	1	Piscium	6	22 46 17·36	+3·067	2	−0·27	−0·25
121	2740	ρ	Pegasi	5·6	22 46 40·35	+3·010	1	+0·78	...
122	2767	m	Pegasi	5·6	23 0 56·90	+3·022	2	+0·08	...
123	2815	15	Piscium	7	23 26 47·29	+3·067	2	+0·66	+0·07
124	2841	n	Piscium	5·6	23 39 12·14	+3·076	2	+0·36	...
125	2863	ψ	Pegasi	5·6	23 49 6·69	+3·040	3	+0·08	...

Notes.

183 A.S.C. Observed with a 20-inch transit.

635 A.S.C. Too bright for a star of the 5·6 mag. The star (17) of this cat. is 2′ 5″ south of *o*′ Orionis, and rather fainter than it.

637 A.S.C. Not noticed as faint.

743 A.S.C. Mean of two observations in 1835 ... ... s. 19·27
" " 1836 ... ... 19·57
" " 1838 ... ... 19·67

779 A.S.C. Mean of three observations in 1835 ... ... s. 55·83
Mean of two observations in 1836 ... ... 56·20

805 A.S.C. Only just visible. Observation made in consequence of Mr. Wrottesley's note upon the star. There are several faint stars in its neighbourhood.

908 A.S.C. Mean of two observations in 1836 ... ... s. 14·80
" " 1838 ... ... 15·00

917 A.S.C. β Canis Minoris. Observed with a 20-inch transit. [Same as in previous catalogue.—Eds.]

1132 A.S.C. A faint star. "Faint" also in Wrottesley's catalogue, but this star was looked for with a declination of +25° 53′ (instead of +26° 53′), and is not the star observed by Wrottesley.

The stars marked 7th mag. in the A.S.C. are by no means of equal brightness.

1336 A.S.C. All four observations greater than Wrottesley.

1548 A.S.C. A faint star.

1651 A.S.C. The five partial results are

s.	
57·31	One observation was made in 1836, and the four following in 1838.
57·41	
57·34	
57·42	
57·44	
Mean ... ... 57·38	[The difference is explained by p.m. −0·06.—Eds.]
Wrottesley ... 57·74	

1709 A.S.C. Marked "too faint" at each observation. "Faint" also in Wrottesley. Mr. Baily has the words "no modern observation" opposite to it in his address.

1752 A.S.C. Excessively faint. Caught with difficulty on two wires. Date of the observation March 24, 1838. This star is called "variable" by Wrottesley.

On the day before (March 23) a star [about 3′ south of 1752 A.S.C., R.A. 15ʰ 19ᵐ 58ˢ·64 (1830)] was observed by mistake for it. [This star is ζ Libræ = B.A.C. 5026.—Eds.]

1918 A.S.C. Greater than Pond +0ˢ·16.

1990 A.S.C. The mean places are

s.	
32·85	observed in 1836
32·56	" 1838
32·70	" 1838

2363 A.S.C. τ Aquilæ. Mean of ten observations with a 20-inch transit, 50ˢ·08 (1830). Greatest difference from the mean 0ˢ·38. [Position from the first catalogue.—Eds.]

N.B.—The second, third, fourth, and sixth columns are copied from the A.S.C.

Note.—The following corrections should be made to Snow's comparisons with other catalogues.—Eds. *M.N.*

		s			s
No. 14.	Greater than A.S.C.	+0·12	No. 61.	Greater than A.S.C.	−0·29
20.	" " "	+0·02	64.	" " "	−0·14
24.	" " "	−0·17	84.	" " "	+0·25
32.	" " Wrottesley	+0·04	88.	" " "	−0·07
40.	" " A.S.C.	+0·35	89.	" " "	−0·07
45.	" " "	+0·34	96.	" " "	+0·24
46.	" " "	−2·77	98.	" " "	−0·20
57.	" " "	−0·03	99.	" " Wrottesley	−0·12
58.	" " "	−0·41	104.	" " A.S.C.	+0·70
59.	" " "	+0·29	125.	" " "	+0·16

Erratum in the Nautical Almanac for 1903.

(*Communicated by the Superintendent of the Nautical Almanac.*)

The assumed mean right ascension for 1903·0 of the star D.M.+16°, 1363 (p. 494 of *Nautical Almanac* 1903) is $4^{s}\cdot5$ too great. In consequence of this the times of occultation of this star on March 8, April 4, and September 15 (pp. 537 and 539) must be diminished by about 2^{m} in each case.

H.M. Nautical Almanac Office:
1903 *June* 11.

MONTHLY NOTICES

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On the possible identity of Nova Geminorum with a small star photographed before the outburst. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. Soon after the announcement of the discovery of Nova *Geminorum*, I heard from Dr. Max Wolf, of Heidelberg, that he had taken a photograph of the region of the Nova on 1903 February 16. This plate is reproduced in *Monthly Notices*, vol. lxiii. plate 13 (opposite p. 330), though by an oversight the letters N and S, E and W, have been transposed; and Dr. Max Wolf remarked, "There is nothing exactly at the place of the Nova, but extremely near to it is a star-like object of about the sixteenth magnitude, and this extends over the place of the Nova, so that the Nova may be a part of this chain-like object."

Dr. Max Wolf kindly sent an enlargement of this negative to the University Observatory, Oxford, and we have measured the position of this object with reference to the stars immediately surrounding it, which have been connected with the Nova micrometrically by Professor Barnard, and also measured here on a plate of 100 min. exposure taken by Mr. Bellamy on April 22.

2. Later we heard that Mr. Parkhurst at the Yerkes Observatory had also photographed the region on February 21 with the 24-inch reflector and an exposure of twenty minutes, showing stars to the 15th or 16th magnitude. The purpose of the photograph was to obtain the region round *X Geminorum*, a variable discovered by Dr. Anderson. The position for 1900·0 of

	R.A.	Decl.
	h m s	° ′
X Geminorum is	6 40 43	+30 23·0
Nova *Geminorum*	6 37 49	+30 2·5

so that the stars near the latter are at the edge of Mr. Parkhurst's plate, and the images are fan-shaped. A positive copy of this plate was kindly sent by Mr. Parkhurst and received at Oxford on June 6. Measures of the same stars have been made on this positive, and also on a negative made from it.

3. The general result of all the measures is not favourable to the supposition that the faint star previously photographed is identical with the Nova, though it does not seem possible to decide the matter conclusively.

4. The stars near the Nova may be conveniently designated by the numbers assigned by Professor E. E. Barnard on p. 5 of *Bulletin* No. 19 of the Yerkes Observatory. His measures have been reduced to "Standard Co-ordinates" (with the Nova as centre) so that they may be compared more readily with measures on photographic plates. For a reason which will presently appear small constants (viz. those entered for n) have been added to all these co-ordinates to reduce them to the mean of the four stars 1, 4, 5, 6. These stars form an irregular quadrilateral enclosing the region of the Nova (n) and the stars 2 and 3; and any systematic errors for stars within this area ought to be smaller than those for the boundary. The columns headed "Oxford" give the differences from Barnard's results of Mr. Bellamy's measures on a plate of 100 min. exposure taken on April 22.

The unit is one réseau interval of 5′ or 300″.

TABLE I.

Standard Co-ordinates of Barnard's Stars and the corrections indicated by Oxford measures.

Star's No.	Barnard.		Oxford.	
	x	y	Δx	Δy
1	+·1332	−·0918	+·0004	·0000
4	−·0493	−·3371	+·0017	+·0017
6	+·1286	+·2637	−·0004	−·0020
5	−·2124	+·1653	−·0009	·0000
2	+·0577	−·2137	+·0021	+·0007
3	−·0303	+·1113	+·0061	−·0017
n	+·0285	−·0644	+·0027	−·0030

5. It will be seen that the agreement for the stars 2, 3, n (the Nova) is not very good, especially in the x co-ordinate. The differences cannot well be due to orientation or scale value, for they would show most in the outer stars. A source of error which has gradually been forced on our attention—what Kapteyn calls the "error of guiding"—seems also inadmissible here, since it produces an effect which increases systematically with the magnitude; and though the stars 2 and 3 are all fainter than 1, 4, 5, 6, and their positive Δx might be due to an "error of guid-

ing," the Nova is of course much brighter and should have a negative residual on this supposition. It seems difficult to account for these errors except as accidental; and, if this is the true view of them, it is worth noting before we pass to the other photographs which have defects from which the Oxford plates ought to be free; viz. they are on a smaller scale, and in the case of Mr. Parkhurst's photograph the images are near the edge of the plate and consequently fan-shaped.

6. Dr. Max Wolf's enlargement was measured both by Mr. Bellamy and myself on April 20, being placed film to film with a réseau for the purpose of measurement. For scale value and orientation five stars were measured, surrounding the region of the Nova and at some distance from it; and it was inferred that measures (x_w, y_w) on the Max Wolf plate were connected with standard co-ordinates (ξ, η) by the approximate formulæ

$$\xi = 0{\cdot}800\, x_w - {\cdot}011\, y_w + \text{const.}$$
$$\eta = 0{\cdot}800\, y_w + {\cdot}011\, x_w + \text{const.}$$

7. It was considered that these coefficients were probably sufficiently exact for application over the small region under examination, the constants being determined from the four stars 1, 4, 5, 6. The images on the enlargement were of very irregular shape, and a more exact determination of the coefficients and constants would require an elaborate discussion of the plate. It may be ultimately necessary to undertake this, but the present preliminary inquiry will at any rate suffice to indicate the limits of possible uncertainty.

8. The Parkhurst plate was measured by Mr. B. Gray and myself on June 11, being first copied on to a plate with a réseau on it. Measures of four stars in different parts of the plate gave for the approximate constants of reduction

$$\xi = -1{\cdot}462\, x_p - {\cdot}0092\, y_p + \text{const.}$$
$$\eta = -1{\cdot}462\, y_p + {\cdot}0092\, x_p + \text{const.}$$

but if these formulæ are applied to the whole plate, the residuals for different stars vary considerably. For the region of the Nova, the co-ordinates of which are about $x_p = 15{\cdot}7$ $y_p = 9{\cdot}6$, the constants differ by about $+\,0{\cdot}030$ in ξ and $+{\cdot}010$ in η from those deduced from the four reference stars, the co-ordinates of which are (10·7, 4·0) (14·2, 2·4) (14·1, 11·2) (11·5, 10·4). It will be seen that these are all on one side of the Nova, which is too near the edge of the plate to allow of reference stars on the other side. It is more than ever necessary to determine the constants from the stars 1, 4, 5, 6, which surround the region under consideration. Mr. Plummer has tried to find some satisfactory method of dealing with plates taken with reflectors, but without much success; perhaps we may hope for better success in the future; but meanwhile we must fall back on the expedient before used,

of trusting an approximate scale value and orientation over the small area, and determining the constants from the four corner stars.

9. I proceed to give the "Corrections to Barnard" indicated by the three photographs. It seems useless to go further than ·001 of a réseau interval, in view of the great uncertainties of the measures. The objects which might be the Nova on the first two plates have been referred to Barnard's position of the Nova as given in Table I.

TABLE II.

Star's No.	Max Wolf, Feb. 16.		Parkhurst, Feb. 19.		Oxford.	
	Δx	Δy	Δx	Δy	Δx	Δy
1	+·001	−·005	−·002	+·001	·000	·000
4	−·005	+·002	+·002	+·003	+·002	+·002
6	+·001	+·004	·000	−·002	−·001	−·002
5	+·002	−·002	·000	−·002	−·001	·000
2	−·001	+·013	−·002	−·001	+·002	+·001
3	−·015	−·002	−·006	−·005	+·006	−·002
n	−·016	−·009	−·021	+·005	+·003	−·003
n'	−·070	−·012	—	—	—	—

10. These figures give us some idea of the limits of error. Star 2 has a residual of +·013 or +4″ in y, which is not supported either by the Parkhurst or the Oxford plate, and must be regarded as accidental. The Max Wolf plate has been magnified five times, and the images are large and irregular. The x measures for star 3 are somewhat remarkable. Both plates taken before the outburst indicate a negative correction to Barnard's measures of March 30, and the Oxford plate, taken on April 22, shows a distinctly positive correction. The figures would be suited by the supposition of a very rapid proper motion (20″ a year say), but this supposition is scarcely admissible, at any rate without further evidence. I wrote to Professor Barnard, hoping that he might have measures on different nights which would give some information. The measures he made were as follows:

Nova and Star 3.

1903 March 30	341°·61	55″·69
April 27	341°·45	(too difficult)

Since a P.M. in R.A. would largely affect the position-angle, these measures are good evidence against any exceptional proper motion.

11. We now come to the question whether the Nova is identical with the small star near its place. The place of the Nova itself seems to be satisfactory, the Oxford measures being in fair agreement with Professor Barnard's. On the Max Wolf plate the image near the place of the Nova is double; in the letter quoted in the first paragraph it is called a "chain-like object." The Parkhurst plate does not support the view that there is a double star at this place, and the double appearance is probably a photographic defect. If it is an elongated image of a single star, we should take some sort of a mean between the positions given for the two condensations n and n'; but the most favourable supposition for identity with the Nova is clearly that n' is spurious, and n is the true image of the star shown on the Parkhurst plate. Even then it differs from the Parkhurst object by ·014 or 4″ in y, in the opposite direction to the difference for star 2. In the light of these discordances, are we to regard the differences from Barnard in the x co-ordinate as merely accidental? If the Max Wolf plate had stood alone, the residuals for stars 2 and 3 would certainly suggest that those for the star n might be accidental; but there is a striking accordance between the x residuals for the two plates which makes one hesitate to believe that the star n can be really the Nova, though this is far from impossible.

12. A word may be said as to the method of measurement. For the Max Wolf plate we simply bisected, as well as possible, the large and irregular images formed. The grain of the film is so large in proportion to them that it seems doubtful whether any systematic errors could be determined. But in the case of the Parkhurst plate, which was taken with a *reflector*, it becomes important to know how far the known systematic errors of reflector photographs could remove or diminish the residuals on a favourable supposition. Reflector images away from the plate centre are fan-shaped, and the apex of the fan corresponds to the ray reflected from the centre of the mirror. If we could measure the exact apex, we should get a true geometrical projection on the plate. Unfortunately the apex is in general cut off by the small mirror (or by the plate-holder itself), and cannot be measured. It is even difficult to estimate its position, owing to the photographic encroachment round the edges of the geometrical image. Mr. Plummer has suggested measuring the transverse axis of the fan, but the results of a trial of this method were not very satisfactory, and we seem almost driven to empirical rather than theoretical methods of measurement. But we may form a fair idea of the possible amount of error by measuring in different ways. The fan-shaped images on the Parkhurst plate were measured by each of two observers in two ways:

(*a*) Estimating the apex of the fan as well as possible.

(*b*) Estimating the centre of the transverse axis as well as possible.

The differences are as below. Of course, if they were constant throughout they would not affect the question at all.

TABLE III.

Star's No.	*x* Diff.		*y* Diff.	
	H.T.	B.G.	H.T.	B.G.
1	+012	+013	+008	+009
4	+009	+012	+008	+009
6	+015	+013	+006	+010
5	+012	+013	+004	+010
2	+006	+006	+004	+007
3	+008	+009	+010	+006
n	+010	+014	+008	+010

It will be clear that we cannot look to any great alteration of the residuals from methods of measurement.

13. On the whole, the evidence seems to be unfavourable to the view that the Nova is identical with the small star photographed before the outburst; but the question cannot be regarded as settled until the light of the Nova has faded sufficiently for search to be made for a small star some 5″ away. For the present it seems best to publish these figures without attempting to draw any final conclusion. But measures of these stars, especially of star 3, will be of great interest until the questions raised are settled.

University Observatory, Oxford:
1903 *August* 12.

P.S. September 14.—The printers' proof of the above was sent back to them yesterday. I have this morning received a letter from Professor Barnard which seems to show that the object photographed on February 16 and 19 is *not* identical with the Nova. He says, under date September 1, "This morning I got your Nova in *Gemini*. There is a small star 14^m preceding it which I measured, and which seems to be Mr. Parkhurst's star:

Position-angle 284°·3 Distance 7″·83.

I shall measure it again. The distances were measured under difficulties of approaching day, but I do not think the result can be more than $\frac{1}{2}''$ out. The Nova has got down to between the 11th and 12th magnitudes. It appeared hazy to me, like a hazy nebulous star. The seeing was good. It looks like Nova *Persei*, but I think is fainter."

A Derivation of Hill's Equation by a Direct Substitution.

By R. A. Herman, M.A.

(*Communicated by the Secretaries.*)

The method and most of the notation is that of Hill's paper on the "Motion of the Lunar Perigee," *Acta Mathematica*, vol. viii.

The equations satisfied by u and s are

$$\left.\begin{aligned} \mathrm{D}^2u + 2m\mathrm{D}u + 2\frac{\partial \Omega}{\partial s} = 0 \\ \mathrm{D}^2s - 2m\mathrm{D}s + 2\frac{\partial \Omega}{\partial u} = 0 \end{aligned}\right\} \quad \ldots \quad \ldots \quad (1)$$

which lead to Jacobi's Integral

$$\mathrm{D}u\mathrm{D}s + 2\Omega = 2C \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

We have if ψ be the angle made by the tangent with the axis of x

$$\mathrm{D}u = \zeta \frac{d}{d\zeta}(x+is) = e^{i\psi}\zeta\frac{d\sigma}{d\zeta}, \quad \mathrm{D}s = e^{-i\psi}\zeta\frac{d\sigma}{d\zeta}$$

where σ is the arc of the curve; or if ϖ denote $\mathrm{D}u \,.\, \mathrm{D}s$,

$$\mathrm{D}u = e^{i\psi}\sqrt{\varpi}, \quad \mathrm{D}s = e^{-i\psi}\sqrt{\varpi}$$

Hence $2i\psi = \log(\mathrm{D}u/\mathrm{D}s)$; and

$$2i\mathrm{D}\psi = \frac{\mathrm{D}^2u}{\mathrm{D}u} - \frac{\mathrm{D}^2s}{\mathrm{D}s} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

This gives $2i\varpi\mathrm{D}\psi = \mathrm{D}^2u\mathrm{D}s - \mathrm{D}^2s\mathrm{D}u$, and on substitution from (1)

$$\begin{aligned} 2i\varpi\mathrm{D}\psi &= -\mathrm{D}s\{2m\mathrm{D}u + 2\Omega_s\} - \mathrm{D}u\{2m\mathrm{D}s - 2\Omega_u\} \\ &= -4m\varpi - 2\Omega_s\mathrm{D}s + 2\Omega_u\mathrm{D}u \end{aligned}$$

Hence

$$\Omega_u\mathrm{D}u - \Omega_s\mathrm{D}s = \varpi(2m + i\mathrm{D}\psi) \quad \ldots \quad \ldots \quad (4)$$

Differentiating (4)

$$\Omega_u\mathrm{D}^2u - \Omega_s\mathrm{D}^2s + (\Omega_{uu}\mathrm{D}u + \Omega_{us}\mathrm{D}s)\mathrm{D}u - (\Omega_{us}\mathrm{D}u + \Omega_{ss}\mathrm{D}s)\mathrm{D}s = (2m + i\mathrm{D}\psi)\mathrm{D}\varpi + \varpi i\mathrm{D}^2\psi$$

or substituting for Ω_u and Ω_s from (1)

$$m(\mathrm{D}u\mathrm{D}^2s + \mathrm{D}s\mathrm{D}^2u) + \Omega_{uu}\mathrm{D}u^2 - \Omega_{ss}\mathrm{D}s^2 = (2m + i\mathrm{D}\psi)\mathrm{D}\varpi + \varpi i\mathrm{D}^2\psi$$

giving the equation

$$(i\varpi\mathrm{D}^2\psi - \Omega_{ss}\mathrm{D}s^2 - \Omega_{uu}\mathrm{D}u^2) = -(m + i\mathrm{D}\psi)\mathrm{D}\varpi \quad \ldots \quad (5)$$

which will be useful later.

Let the point on the variational orbit receive an arbitrary tangential displacement δT and a normal displacement δN; then the corresponding values of δu, δs are respectively $(\partial T - i\partial N)e^{i\psi}$ and $(\delta T + i\partial N)e^{-i\psi}$.

Now subject the Jacobi Integral to an arbitrary variation,

$$Ds D\delta u + Du D\delta s + 2\Omega_u \delta u + 2\Omega_s \delta s = 0$$

or with the values for Du, Ds above

$$\begin{aligned} & e^{-i\psi}\sqrt{\varpi}e^{i\psi}\{D(\partial T - i\partial N) + (\delta T - i\partial N)iD\psi\} \\ & + \sqrt{\varpi}\ \{D(\partial T + i\partial N) - (\partial T + i\partial N)iD\psi\} \\ & + 2\Omega_u(\delta T - i\delta N)\frac{Du}{\sqrt{\varpi}} + 2\Omega_s(\partial T + i\delta N)\frac{Ds}{\sqrt{\varpi}} = 0 \end{aligned}$$

whence

$$\varpi D\delta T + \delta T . D\Omega + \varpi D\psi . \delta N + (\Omega_s Ds - \Omega_u Du) i\partial N = 0$$

On substitution from (2) and (4) this gives

$$[\varpi D - \tfrac{1}{2}D\varpi]\delta T = 2\varpi(m + iD\psi)i\delta N \quad \ldots \quad \ldots \quad (6)$$

We then vary the first equation of motion and obtain

$$D^2\delta u + 2mD\partial u + 2\Omega_{uu}\delta u + 2\Omega_{us}\partial s = 0$$

or on substitution

$$\begin{aligned} & e^{i\psi}[D^2(\partial T - i\partial N) + 2(m + iD\psi)D(\partial T - i\partial N) \\ & \quad + (iD^2\psi + 2miD\psi - D\overline{\psi}^2)(\partial T - i\partial N)] \\ & \quad + 2\Omega_{us}e^{i\psi}(\partial T - i\partial N) + 2\Omega_{ss}e^{-i\psi}(\partial T + i\partial N) = 0 \end{aligned}$$

and the equation obtained by varying the second equation of motion differs only in having the signs of i and m changed and Ω_{uu} in place of Ω_{ss}. Multiply these two equations by $e^{-i\psi}$, $e^{i\psi}$ and subtract; we obtain

$$\begin{aligned} & 2(m + iD\psi)D\partial T + (iD^2\psi + e^{-2i\psi}\Omega_{ss} - e^{2i\psi}\Omega_{uu})\delta T \\ & \quad = D^2 i\partial N + (2miD\psi - D\overline{\psi}^2)i\partial N \\ & \qquad + (2\Omega_{us} - e^{-2i\psi}\Omega_{ss} - e^{2i\psi}\Omega_{uu})i\delta N. \end{aligned}$$

Putting $(Ds)^2/\varpi$ for $e^{-2i\psi}$ and $(Du)^2/\varpi$ for $e^{2i\psi}$ the coefficient of ∂T on the left is $-\frac{1}{\varpi}(m + iD\psi)D\varpi$ by (5), and hence substituting from (6) the value of the left-hand side is $4(m + iD\psi)^2 i\partial N$.

The equation satisfied by ∂N is therefore $D^2\partial N = \Theta\partial N$, where

$$\Theta = m^2 + 3(m + iD\psi)^2 + e^{2i\psi}\Omega_{uu} - 2\Omega_{us} + e^{-2i\psi}\Omega_{ss}$$

It is easy to verify by change of variables that the terms involving Ω in this expression for Θ are $-\dfrac{\partial^2\Omega}{\partial N^2}$.

We have yet to express $-\frac{\partial^2 \Omega}{\partial \bar{N}^2}$ in terms of the differentials of u and s.

Now $-\frac{1}{2}D\varpi = D\Omega = \Omega_u Du + \Omega_s Ds.$

Hence $-\frac{1}{2}D^2\varpi = \Omega_u D^2u + \Omega_s D^2s$

$$+ \Omega_{uu}(Du)^2 + 2\Omega_{us}DuDs + \Omega_{ss}(Ds)^2$$

$$= -\Omega_u(2mDu + 2\Omega_s) + \Omega_s(2mDs - 2\Omega_u)$$

$$+ \varpi\{e^{2i\psi}\Omega_{uu} + 2\Omega_{us} + e^{-2i\psi}\Omega_{ss}\}$$

$$= -2m\varpi(2m + iD\psi) - 4\Omega_u\Omega_s$$

$$+ \varpi\{e^{2i\psi}\Omega_{uu} + 2\Omega_{us} + e^{-2i\psi}\Omega_{ss}\}$$

Also $4\Omega_u\Omega_s = \{(\Omega_u Du + \Omega_s Ds)^2 - (\Omega_u Du - \Omega_s Ds)^2\}/\varpi$

$$= \frac{1}{\varpi}(D\Omega)^2 - \varpi(2m + iD\psi)^2$$

and this gives on substitution

$$e^{2i\psi}\Omega_{uu} - 2\Omega_{us} + e^{-2i\psi}\Omega_{ss}$$

$$= -\frac{1}{2\varpi}D^2\varpi + \frac{1}{4\varpi^2}(D\varpi)^2 + m^2 - (m + iD\psi)^2 - 4\Omega_{us}$$

$$= -D\left(\frac{D\varpi}{2\varpi}\right) - \left(\frac{D\varpi}{2\varpi}\right)^2 + m^2 - (m + iD\psi)^2 - 4\Omega_{us}$$

and since $$\Omega = \frac{K}{(us)^{\frac{1}{2}}} + \tfrac{1}{8}m^2(u+s)^2,$$

$$\Omega_{us} = \tfrac{3}{4}\frac{K}{r^3} + \tfrac{3}{4}m^2,$$

whence

$$\Theta = -\left(\frac{K}{r^3} + m^2\right) + 2(m + iD\psi)^2 - D\left(\frac{D\varpi}{2\varpi}\right) - \left(\frac{D\varpi}{2\varpi}\right)^2,$$

which is Hill's form.

On the Construction of Telescopes whose Relative or Absolute Focal Length shall be Invariable at all Temperatures. By F. L. O. Wadsworth.

(*Communicated by the Secretaries*)

In the case of all optical instruments which are designed for the accurate measurement of either relative or absolute positions it is extremely necessary to avoid the necessity for refocussing the instrument for changes of temperature. Such refocussing is likely to produce both errors of measurement and errors of adjustment. The first have already been dealt with in

a recent paper,* where the effect of refocussing is considered especially with reference to spectrometric, heliometric, and micrometric observations.† The second class of errors are more purely mechanical in their nature, and apply more particularly to measurements with the transit, meridian circle, zenith telescope, &c. Here the effect is to disturb the position of the axis of collimation, and may, of course, be eliminated by a redetermination of that constant. Such disturbances and readjustments are, however, to be avoided whenever possible. My attention was first called to this problem in working out the design of the proposed 6″ photographic transit and meridian circle for the new Allegheny Observatory,‡ and more recently by the experiences of Professor Updegraff with the new 6″ meridian circle of the U.S. Naval Observatory. Professor Updegraff found that the apparent focal length of this instrument was decidedly different at different seasons of the year. No such result had ever before been observed with any of the other similar instruments at the observatory, and Professor Updegraff stated to me that some of the observers there disputed and even ridiculed the idea of such a change taking place; but, as a matter of fact, both the variability of the apparent focal length of the 6″ and the invariability of the focal length of the other instruments are fully explained and might have been predicted, by theory. There are a few points of interest in this connection which it has seemed desirable to develop.

The variability of the focal length of a refracting objective at different temperatures has been long known, but the cause of this variability does not seem to be well understood. The theory of the subject seems to have been first investigated by Krueger.§ Later, Sundell made an extended series of measurements of the focal length of the Helsingfors heliometer, and found‖ that the results obtained differed by more than 20 per cent. from those given by Krueger's formulæ. It was immediately pointed out by Professor Hastings¶ that this difference was probably due in large part to the error in Professor Krueger's assumption that the "refractive power" of a glass varies directly as the density. This assumption is now well known to be incorrect. The expression derived by Professor Hastings for the variation, ΔF, of the focal length of an objective for a difference in temperature, ΔT, is as follows:

$$\Delta F = -F^2\left[\frac{dn_1}{dt}A + (n_1 - 1)\frac{dA}{dt} + \frac{dn_2}{dt}B + (n_2 - 1)\frac{dB}{dt}\right]\Delta T \quad (1)$$

* "On the Optical Conditions required to secure Maximum Accuracy of Measurement in the Use of the Telescope and Spectroscope," *Astrophysical Journal*, vol. xvi. pp. 267–299; vol. xvii. pp. 1–19, 100–132.

† See particularly vol. xvii. pp. 7–19.

‡ See Report of the Director, 1900. pp. 8 and 29; *ibid.* 1901, p. 16.

§ *Astronomische Nachrichten*, Bd. 60, s. 65.

‖ *Ibid.* Bd. 103, s. 19–26; also Bd. 111, s. 257–262.

¶ *Ibid.* Bd. 105, s. 69–72.

where n_1 and n_2 are the indices of refraction of the crown and flint glasses for the wave-length corresponding to any given spectral focus of the objective, and A, B are the sums of the curvatures of the surfaces of the two lenses. All four differential coefficients, $\frac{dn}{dt}$ and $\frac{dA}{dt}$, must be determined by experiment.

The above expression (1) is derived directly from the differentiation of the usual expression for the focal length of a compound (achromatic) lens, and neglects the effect of thickness and separation of the two lenses. Ordinarily the effect of these quantities on the differential changes of focal length with temperature will be themselves differentials of a second order, and may be neglected. Within these limits therefore (1) is rigorously correct, provided the refraction coefficients $\frac{dn}{dt}$ are properly interpreted and measured. This last precaution, however, is an important one, and does not seem to have always been regarded. Thus Professor Hastings himself, in applying the formula to the calculation of the focal length of a given lens, seems to have used for $\frac{dn_1}{dt}$ and $\frac{dn_2}{dt}$ values derived from the measurements of variations in the *relative* indices of glass and air. This is correct only when the temperature of the lens is the *same* as that of the air and both change uniformly. Generally this last condition is not fulfilled, and we must then express $\frac{dn}{dt}$ with reference not to the *relative* index of refraction n, but with reference to the *absolute* indices, n_o and N_o, of glass and air respectively.

From the well-known relation

$$n = \frac{n_o}{N} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

we have

$$\frac{dn}{dt} = \frac{1}{N}\frac{dn_o}{dt} - \frac{n_o}{N^2}\frac{dN}{dt} \simeq \frac{dn_o}{dt} - n\frac{dN}{dt} \quad \ldots \quad (3)$$

since N is itself very nearly equal to unity at all temperatures.

The value of the second term of (3) for any particular glass is nearly constant. According to the most recent determinations, the thermal refractive coefficient for air at ordinary pressure and temperature (760 mm. and 20° C.) is

$$\frac{dN}{dt} \simeq -0{\cdot}93 \times 10^{-6} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

For the flint and crown glasses, Feil 1237 and Feil 1219,

investigated by Professor Hastings, the relative temperature coefficients for wave-lengths 5600 are*

$$\left.\begin{array}{l}\text{Crown } 1219,\ \dfrac{dn_1}{dt} = +0{\cdot}1 \times 10^{-6} \\ \text{Flint } \ 1237,\ \dfrac{dn_2}{dt} = +5{\cdot}4 \times 10^{-6}\end{array}\right\} \quad \ldots \quad \ldots \quad (5)$$

The relative indices, n, for these two glasses for the same wave-lengths are

$$n_1 = n_{1219} = 1{\cdot}519+$$
$$n_2 = n_{1237} = 1{\cdot}628$$

Hence the absolute temperature coefficients $\dfrac{dn_0}{dt}$ are found to be

$$\text{For crown } 1219,\ \frac{dn_0}{dt} \simeq -1{\cdot}31 \times 10^{-6}$$

$$\text{For flint } 1237,\ \frac{dn_0}{dt} \simeq +3{\cdot}9 \times 10^{-6}$$

The effect on the focal length of a given change in the temperature of the air in the telescope tube is therefore very nearly equal to the effect of the same change in the temperature of the crown glass, and is not quite one-third as great as that produced by an equal temperature variation in the flint. In the first case the effects are nearly compensatory; in the second case they are additive. Hence any difference in the temperature variation, Δt, of the air and the objective will produce a decided difference in the quantity $\dfrac{dn}{dt}$ which appears in (1) and (3), and will lead to a corresponding difference in ΔF. In general the temperature change in the glass will lag behind that in the surrounding air; hence, if the temperature is rising the quantity $\dfrac{dn}{dt}$ will be smaller than would be indicated by measurement, and the observed focal length will be shorter than that calculated for the given air temperature; if the temperature is falling, the reverse will be the case, and the measured focal length will be longer than the calculated. This fact may explain the discrepancies that have been sometimes observed in measuring the variations of focal length with temperature.

The magnitude of the differential change in the focal length of a given telescope is dependent upon the nature of the glass employed in its construction. For the purpose of comparison I have collected the results of measurements on a number of different object-glasses of different sizes and types of construction, which are presented in the following table:—

* *American Journal of Science*, vol. xv. p. 269.

TABLE I.

Instrument.			Change in F.				Conditions of Observation.		
Objective.	A	F.	ΔT(C).	ΔF (apparent).	ΔZ (tube).	Total $\frac{\Delta F}{F\Delta T} = a''$.	Observer.	Reference.	Remarks.
	cm.	cm.	°	cm.	cm.				
Helsingfors	...	...	28·1	0·177		2·19 × 10−5	Sundell	Ast. Nach. Vol. ciii. p. 24	Winter of 1879 16°·2 C. to −11°·9 C.
Heliometer	...	298·3	31·9	0·211		2·29 × 10−5	Sundell	Vol. cxi. p. 261	Winter of 1881 17°·3 C. to −14°·6 C.
Strassburg Heliometer	...	691·6	27·8	1·08		5·1 × 10−5	Schur	Ast. Nach. Vol. cxix. p. 249	+24°·6 C. to −3°·2 C.
Göttingen Heliometer	...	...	About 40	...		2·06 × 10−5	Schur	Ambronn. Handbuch	—
Emerson McMillen	30·5	457·2	27·5	0·18	0·13*	2·46 × 10−5	Lord	Astrophysical Journal, Vol. v. p. 305	Change measured for H_β
Halstead	58·4	917·7	30·0	Very small	0·22†	1·17 × 10−5	Young	From unpublished observations	Never very carefully observed
Washington	66·0	990·0	About 24·4	0·24	0·27†	2·11 × 10−5	See and Dinwiddie	Report U.S. Naval Obs. 1902	Visual change
Lick	91·4	1763· +	30	1·7	0·6*	4·3 × 10−5	Campbell	Astrophysical Journal, Vol. viii. p. 138	Change measured for H_γ
Yerkes	102·0	1936· +	50	0·72	0·97*	1·64 × 10−5	Hale and Ellermann	Astrophysical Journal, Vol. x. p. 93.	Not stated, probably visual

* Computed for steel tube.

† Computed for combination tube (steel and brass).

The wide variations in the absolute values of the temperature co-efficients a'' is remarkable, and seems to indicate that little attention has been paid to the question of controlling or eliminating changes in focal length. But as already stated, this question is an important one in the case of instruments designed for accurate measurements, and should in such cases be quite as carefully considered as any of the other optical problems connected with the design of objectives.

In general, the condition which we desire to fulfil is that the apparent focal length of the instrument shall remain unaltered. This means that the coefficient of change in focal length a'' shall be equal to the coefficient of linear expansion a_t of the metal of which the tube of the telescope is constructed, *i.e.*

$$a'' = \frac{\Delta F}{F} = a_t = \frac{\Delta Z}{Z} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

Equation (1) may be put in the form

$$\frac{\Delta F}{F} = -F\left\{\frac{dn_1}{dt}A + \frac{dn_2}{dt}B - a_g\left[(n_1 - 1)A + (n_2 - 1)B\right]\right\}\Delta t$$

or for one degree change in temperature, ($\Delta t = 1$)

$$\frac{\Delta F}{F} = a'' = a_g - F\left(\frac{dn_1}{dt}A + \frac{dn_2}{dt}B\right) \quad \ldots \quad (7)$$

where a_g is the coefficient of linear expansion of the glass, which is assumed to be the same for both flint and crown.

In order to satisfy the conditions of achromatism, we must also have for A and B—

$$\left.\begin{aligned} A &= \frac{1}{F\Delta n_1\left[\frac{n_1 - 1}{\Delta n_1} - \frac{n_2 - 1}{\Delta n_2}\right]} \\ B &= \frac{1}{F\Delta n_2\left[\frac{n_2 - 1}{\Delta n_2} - \frac{n_1 - 1}{\Delta n_1}\right]} \end{aligned}\right\} \quad \ldots \quad \ldots \quad (8)$$

Substituting these values of A and B in (7) we obtain

$$\left.\begin{aligned} a'' &= a_g - \frac{\frac{dn_1}{dt}}{\Delta n_1\left[\frac{n_1 - 1}{\Delta n_1} - \frac{n_2 - 1}{\Delta n_2}\right]} - \frac{\frac{dn_2}{dt}}{\Delta n_2\left[\frac{n_2 - 1}{\Delta n_2} - \frac{n_1 - 1}{\Delta n_1}\right]} \\ &= a_g + \frac{1}{\frac{n_1 - 1}{\Delta n_1} - \frac{n_2 - 1}{\Delta n_2}}\left[\frac{1}{\Delta n_2}\frac{dn_2}{dt} - \frac{1}{\Delta n_1}\frac{dn_1}{dt}\right] \end{aligned}\right\} \quad (9)$$

and the problem is to choose two glasses (crown and flint) whose

optical properties are such as to make the numerical value of a'' from (9) satisfy the condition expressed in (6)

Through the researches of Fizeau,* Hastings,† Müller,‡ Vogel,§ Pulfrich,‖ Reed,¶ and Winkelmann** we now have available the constants a_ρ, n, Δn, and $\frac{dn}{dt}$ for a considerable number of flint and crown glasses. These values are collected together in the following table :—

* *Annales de Chimie et de Physique* (3), vol. lxvi. p. 429.
† *American Journal of Science* (3), vol. xv. p. 269.
‡ *Publicationen des Astrophysicalischen Observatoriums zu Potsdam*, vol. iv. p. 151.
§ Wiedmann, *Annalen*, vol. xxv. p. 87.
‖ *Ibid.* vol. xlv. p. 609.
¶ *Inaugural-Dissertation*, Jena, 1897.
** Wiedmann, *Annalen*, 1892 to 1897.

TABLE

Glass.	Maker's Number.	Sp. gr.	α_t $\times 10^{-6}$	n for D.	$\frac{1}{\Delta n}(n_D - 1)$ C–F.
Flint	Feil 1237	3·554	8·5	1·62542	36·1
Flint	„ 1241	3·151		1·58091	41·0
Crown	„ 1219	2·482		1·51796	58·5
Crown (Zinc)	Maes	2·626	8·5	1·5204	...
Flint (ordinary)	...	3·584	8·1	1·6112	...
Dense Flint	...	4·14	6·6	1·682	...
Flint	Schröder	3·855	...	1·65129	33·8
Flint	„	3·642	...	1·62461	36·5
Flint	„	3·218	...	1·57991	41·4
Crown	„ 1308	2·519	...	1·51767	59·3
Crown	„ 1313	2·522	...	1·51614	58·6
White Glass	...	...	...	1·61399	36·5
Heavy Flint	...	...	...	1·75968	26·8
Super Dense Silicate Flint	S 57	6·33	9·3	1·9625	19·7
Extra Dense „ „	O 165	...	8·0	1·7545	27·6
Ordinary „ „	O 544	...	...	1·6130	37·1
Light „ „	O 154	...	7·9	1·5710	43·1
Light Barium Flint	O 527	3·19	9·0	1·5718	50·6
Light Borosilicate Flint ...	O 658	...	5·2	1·5452	50·3
Heavy Barium Silicate Crown	O 211	3·21	...	1·5727	58·0
Phosphate Crown ...	S 40	3·07	...	1 5619	66·5
Ordinary Silicate Crown	O 1022	...	9·6	1 5173	60·2
Light Phosphate „	O 225	2·58	...	1·5160	70·3
Borosilicate „	O 627	...	8·0	1·5128	63·7
Light Borate . „	S 205	...	6·7	1·5075	60 6
Super Dense Silicate Flint	S 163	...	...	1·8904	22·3
Flint	O 1299	...	...	1·6099	57·7

The desired equality between α_t and α'' required to fulfil the condition of apparent invariable focal length may be obtained by varying either α_t or α'', *i.e.* by a suitable choice either of the material of which the telescope tube is made, or of the glasses which are used in the construction of the objective.

The materials at our practical disposal for the telescope tube, and their thermal co-efficients of expansion, α_n are as follows :

Zinc $\quad \alpha_t = \alpha_2 \tilde{=} +29$ to 30×10^{-6}

Aluminium $\quad = \alpha_n \tilde{=} +23 \times 10^{-6}$

II.

$\frac{dn_o}{dt}$ for D. 1×10^{-6}	$\frac{dn}{dt}$ for D 1×10^{-6}	n for G.	$\frac{1}{\Delta n}(n_{G-1})$ F−H	$\frac{dn_o}{dt}$ for G 1×10^{-6}	$\frac{dn}{dt}$ for G 1×10^{-6}	Observer.
+ 3·9	+ 5·07	1·64909	29·5	...	+ 7·85	Hastings.
...	+ 2·61	1·60013	34·0	...	+ 4·51	
− 1·31	− 0·08	1·52960	51·5	...	+ 1·44	
...	0·0	...	...	...	...	Fizeau.
...	+ 2·6	...	...	...	...	
...	+ 6·87	...	...	...	...	
...	+ 5·3	1·67688	...	...	+ 7·8	Müller.
...	+ 6·2	1·64725	30·5	...	+ 8·7	
...	+ 3·6	1·59831	35·1	...	+ 5·6	
..	− 0·09	1·52880	53·5	...	+ 1·1	
...	− 0·01	1·52737	52·6	...	+ 1·1	
...	+ 2·4	1·636033	...	...	+ 4·3	Vogel.
...	+ 3·2	1·78915	...	...	+ 8·0	
+ 14·5	+ 15·9	2·0303	...	+ 28·1	+ 29·5	Pulfrich.
+ 7·7	+ 9·1	1·7914	...	+ 13·1	+ 14·4	
+ 2·8	+ 4·0	1·6348	31·1*	+ 5·0	+ 6·2	
+ 2·6	+ 3·7	1·5883	36·8*	+ 4·1	+ 5·2	
+ 0·14	+ 1·25	1·5864	41·9*	+ 1·37	+ 2·5	
+ 3·0	+ 4·1	1·5591	...	+ 4·1	+ 5·2	
+ 0·4	+ 1·5	1·5852	...	+ 1·4	+ 2·55	
− 3·05	− 1·94	1·5725	...	− 2·37	− 1·24	
− 1·05	+ 0·04	1·5281	54·0*	− 0·10	+ 1·0	
− 1·90	− 0·80	1·5252	...	− 1·42	− 0·31	
+ 1·37	+ 2·51	1·5229	57·5*	+ 2·13	+ 3·29	
− ·74	+ ·33	1·5179	54·5*	− 0·0	+ 1·06	
+ 12·8	+ 14·10	1·9441	...	+ 21·6	+ 23·0	Reed.
+ 4·1	+ 5·25	1·6231	...	+ 5·3	+ 6·4	

Brass and Bronze	$= a_b \simeq +18$ to 19×10^{-6}
Copper	$= a_c \simeq +16$ to 17×10^{-6}
Steel and Iron	$= a_s \simeq +10$ to 13×10^{-6}
Glass	$= a_g \simeq +6$ to 9×10^{-6}
Wood	$= a_w \simeq +0{\cdot}3$ to $0{\cdot}8 \times 10^{-6}$
Nickel Steel	$= a_n \simeq +0{\cdot}1$ to $0{\cdot}5 \times 10^{-6}$

Of these only aluminium, brass, copper, steel, and nickel steel are suitable for large telescopes. These metals offer a range of values for a from 0 to 23×10^{-6}. In order to fulfil the general condition in (6) the thermal coefficient of focal change a'' must therefore not exceed the first figure, *i.e.* 23×10^{-6}. If the absolute focal length is to remain invariable, both a_l and a'' must be zero.

Since a_b, a_g, n, dn and $\frac{dn}{dt}$ are all themselves functions of t, it is necessary to choose some common standard temperature, t_0, which will be a mean of the extremes within which we desire to secure compensation. For laboratory work the value of t_0 will be about 20° C., and the maximum range of temperatures will probably not exceed $\pm 10°$ C. For astronomical work the mean temperature t_0 will be about 10° lower, *i.e.* $t_0 = 10°$ C., and the maximum range may be as large as $\pm 20°$, *i.e.* from $-10°$ C. to $+30°$ C. Since the variability of the various optical constants which appear in (9) with temperature will prevent *exact* compensation for all values of t, it is important to fix the limits within which variations of focus may be permitted without detriment to the optical performance of the instrument. If the instrument is used simply for visual work, and no requirement more severe than that of "good definition" is imposed, the permissible variation in focus will be *

$$\delta F = \frac{\lambda}{\beta^2} \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

where β is the semi-angular aperture of the lens. For purpose of comparison with (6) and (9) we may put this in the form

$$\frac{\delta F}{F} = \frac{2\lambda}{a} \cdot \frac{1}{\beta} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

The absolute value of the permissible variation in focus δF is the same, (10), for all instruments having the same form (*i.e.* same angular aperture). The percentage change $\frac{\delta F}{F}$ is inversely proportional to the linear aperture, a, as well as to the semi-angular aperture, β. In the case of an ordinary meridian circle, β is not far from 0·04 and a is about 15 cm. Hence for minimum focus, for which λ is about 0·000056 cm., we have

$$\frac{\Delta F}{F} \sim = 185 \times 10^{-6}$$

as the extreme permissible variation of focus with temperature. If the range of t is 40°, as assumed above, this gives as the permissible range for 1°

$$\frac{\delta F}{F} = a'' - a \sim = 4{\cdot}6 \times 10^{-6} \quad \ldots \quad \ldots \quad (12)$$

* Lord Rayleigh "On the Accuracy of Focus required for Sensibly Perfect Definition," *Phil. Mag.*, vol. xx, p. 354.

Hence in this case, if the values of a'' and a_t agree within four units in the sixth decimal place, there will be no *apparent* change in focus over a range of 40° C.

With the ordinary flint and crown glasses, Feil 1237 and 1219, used by Hastings, the value of a'' is found to be *

$$a'' = 22 + \times 10^{-6} \quad \ldots \quad \ldots \quad (13)$$

The values of a for brass, the material of which the tubes of nearly all our transits and meridian circles are composed, is about 18×10^{-6}. The apparent change in focus for 1° C. of an instrument so constructed is

$$\frac{\delta F}{F} = \delta_F = a'' - a_b = 4 \times 10^{-6} \quad \ldots \quad \ldots \quad (14)$$

which is well within the limit imposed by (12). Such an instrument will, as a matter of fact, maintain an apparently invariable focus over a range of temperature of nearly 50° C.; a considerably greater range than is ever met with in astronomical work of precision. Observers with meridian circles of the usual construction may thus be readily led to doubt the existence of any relative change in focus in such instruments.

If, however, we construct the telescope tube of steel, as in the case of the new Washington 6″ meridian circle and 5″ alt-azimuth, we have for the same objective above considered

$$\delta_F = a'' - a_s \cong \times \quad 10^{-6}$$

and in this case the apparent focus would change for any temperature variation exceeding 15°. For a difference of temperature of 25° C., which is about the range of temperature at Washington, the total apparent variation in focus of the 6″ (focal length 182·9 cm.) will be

$$\delta F = 3 \times 10^{-4} F$$
$$= \cdot 055 \text{ cm.}$$

or a little over two one-hundredths of an inch. This is almost exactly the amount of variation found by Prof. Updegraff.†

An examination of Table I. shows that in the case of visual refractors the value of a'' ranges from about that computed in (13) to one about 50 per cent. larger. The results of the preceding comparison show that in order to obtain compensation with a steel tube, the values of a'' must be reduced about one-half. Since the value of a_t for most glass is not far from 8×10^{-6}, it follows that the term involving the relations between n, Δn, and $\frac{dn}{dt}$ must be nearly zero to secure the desired equality between the values of a'' and a_s (steel tube). The dispersion

* *Astronomische Nachrichten*, Bd. 105, s. 62.

† From data communicated in advance by Prof. Updegraff. See also Vol. III. *Publications of the United States Naval Observatory*, Part iv., p. D. vi.

coefficients $\frac{n-1}{\Delta n}$ are always considerably larger for crown glass (n_1) than for flint glass (n_2), and the coefficient of the quantity within the brackets is therefore always positive and greater than zero. The mean dispersion Δn_2 of flint glass is, on the contrary, always larger than the corresponding quantity Δn_1 for crown, and by an examination of the values of $\frac{dn}{dt}$ in Table II. we find that in general this refraction coefficient is likewise much larger for flint than for crown. To reduce the value of a'' it is therefore necessary to choose a flint and crown in which the ratios $\frac{dn}{dt} : \Delta n$ are nearly equal. For convenience of comparison I have computed this ratio, which we will designate by R, for each of the glasses of Table II. for the region near D (for which visual objectives are corrected) and also for the region near G (for photographic objectives) whenever the data available were sufficient for the latter determination. The results, together with the values of a_1, and of the dispersion coefficients $\frac{n-1}{\Delta n}$, taken from Table II., are arranged systematically for the flints and crowns separately in Table III. and Table IV.

TABLE III.

Flints.

GLASS	a'	D Region (Visual Objectives) $\frac{n_2-1}{\Delta n_2} = D_2$	R_2	G Region (Photographic Objectives) $\frac{n_2-1}{\Delta n_2} = D'_2$	R'_2	Remarks with Reference to Physical Properties.
	1×10^{-6}		1×10^{-6}		1×10^{-6}	
Densest Silicate S 57	9·3	19·7	326	...	...	Very yellow.
Silicate S 163	...	22·3	353	...	...	,,
Dense Vogel (V) ...	...	26 8	113	...	...	,,
Silicate O 165 ...	8·0	27·6	332	...	...	
Schroeder (S_1) ...	...	33·8	276	...	...	
Feil 1237	8·5	36·1	293	29·5	357	
Schroeder (S_2) ...	...	36·5	362	30·5	410	
White Flint (V_2) ...	...	36·5	143	...	...	
Ordinary Flint O 544... ...	...	37·1	244	31·1	304	Good.
Feil 1241	8·5	41·0	185	34·0	255	
Schroeder (S_3) ...	...	41·4	257	35·1	321	
Light Silicate O 154	7·9	43·1	280	36·8	325	
Borosilicate O 658	5·2	50·3	379	...	...	Very permanent.
Barium O 527 ...	9·0	50·6	111	41·9	179	Not good.
,, O 1299		57·7	387	...	...	

TABLE IV.

Crowns.

GLASS.	a_t 1×10^{-6}	D Region (Visual Objectives) D_t	R_t 1×10^{-6}	D Region (Photographic Objectives) D'_t	R'_t 1×10^{-6}	Remarks on Physical Properties.
Heavy Barium Silicate O 211	...	58·0	+152·0	...	...	Liable to tarnish.
Feil 1219 ...	8·5	58·5	− 9·0	51·5	140	
Schroeder 1313 ...	...	58·6	− 1·14	52·6	110	
„ 1308 ...	...	59·3	− 10·4	53·5	111	
Ordinary Silicate O 1022 ...	9·6	60·2	+ 4·65	54·0	102	
Light Borate S 205	6·7	60·6	+ 39·3	54·5	112	Must be protected in use.
Borosilicate O 627	8·0	63·7	+310·0	57·5	362	Very permanent.
Phosphate S 40	...	66·5	−229·0	...	...	Not desirable.
Light Phosphate O 225 ...	...	70·3	−110·0	...	...	

By proper selection of the flint and crown from these two tables we can obtain objectives having almost any desired value of a''. A few examples may be of interest.

(A). For $a'' = a_b$ (brass tube mounting)

(1) The combination of Feil 1237 (flint) with Feil 1219 (crown) gives, as already stated, an objective whose coefficient a'' of focal length variation is so close to that of brass that the apparent focal length of such an objective in a brass tube will remain apparently invariable over a range of 50° C.

A still more accurate compensation may be obtained by (2) the combination of ordinary silicate flint, O 544, with ordinary silicate crown, O 1022. The mean thermal coefficient of expansion a_g of these glasses is about $9\cdot5\times10^{-6}$. We obtain for a''

$$a'' = \left[9\cdot5 + \frac{1}{60\cdot2-37\cdot1}(\cdot244-4\cdot7)\right]\times10^{-6}$$
$$= 19\cdot5\times10^{-6}$$

The coefficient of apparent change in focus for such an objective in a brass mounting for 1° C. is therefore

$$\delta_F = (19\cdot5-18 = 1\cdot5)\times10^{-6}$$

and by comparison with (11) and (12) we see that for instruments of less than 6″ aperture the compensation is apparently perfect over a range of more than 100° C. For instruments up

to 12″ aperture the compensation is effective over a range of 50° C.

(B)$_F$ For $\alpha'' = \alpha_s$ (steel tube compensation).

To secure this result it is necessary, as already stated, to use glasses for which R_1 and R_2 are nearly equal. Two combinations which satisfy this condition are as follows :—

(1) Combine Feil 1241 (flint) with a heavy barium silicate crown, O 211. The mean value for the coefficient α_g for these glasses is about $8{\cdot}5 \times 10^{-6}$. For α'' we have

$$\alpha'' = \left[8{\cdot}5 + \frac{1}{58-41}(185-152)\right] \times 10^{-6}$$
$$= 10{\cdot}5 \times 10^{-6}$$

and $$\delta_F \tilde{=} 0{\cdot}5 \times 10^{-6}$$

which would ensure compensation (for a 6″ objective) over a range of nearly 300° C. The combination, however, will require quite thick lenses and relatively deep curves to secure the necessary corrections for spherical and chromatic aberration. The barium silicate crowns are also less permanent than some of the others. A better combination is as follows :

(2) Combine Feil 1237 (flint) with a borosilicate crown O 627. This gives for α''

$$\alpha'' = (8{\cdot}5 - 6 = 7{\cdot}9) \times 10^{-6}$$

and $$\delta_F = 2{\cdot}1 \times 10^{-6}$$

which ensures compensation (for 6″ objective) over a range of more than 80° C.

(C)$_F$ For $\alpha'' = 0$ (focal length invariable).

To secure this condition we must necessarily use a crown having a large positive value of R. The only crowns in the above list which satisfy this condition are the two used in the combinations ($\alpha'' = \alpha_s$) just considered. With these we must use flints whose thermal variations are small—*i.e.* dense flint, V_1; white flint, V_2 Feil 1241, or light barium flint, O 527. The commercial source of the first two is uncertain, and the last is unsatisfactory—in fact, inadmissible, in combination with the first crown mentioned (O 211). The best combination therefore appears to be :

(1) Flint, Feil 1241, with crown O 627. This gives

$$\alpha'' = [8{\cdot}5 - 5{\cdot}5 = 3] \times 10^{-6}$$

which is invariable within limits of possible accuracy of focussing over a range of about 60° C. for a 6″ objective.

In the case of photographic objectives the conditions of com-

pensation and absolute invariability of focus are met by the combinations:

$(A)_p$ Compensation in brass-tube mounting.

Flint O 344 (ordinary) and crown O 1022 (ordinary).

$$a'' \cong 18 \times 10^{-6} \text{ and } \delta_p \cong 0{\cdot}0$$

$(B)_p$ Compensation in steel-tube mounting.

Flint, Feil 1237, and crown O 627.

$$a'' = a_1 = 8{\cdot}5 \times 10^{-6} \text{ and } \delta_p = 1{\cdot}5 \times 10^{-6}$$

$(C)_p$ Constant focal length.

Flint, Feil 1241, and crown O 627.

$$a'' \cong 3{\cdot}6 \times 10^{-6},$$

Or flint O 527, and crown O 627.

$$a'' \cong -2{\cdot}5 \times 10^{-6}.$$

It is to be noted that all the above results are obtained without imposing any conditions as to radii of curvature of either of the lenses, and therefore without sacrifice of any of the usual optical requirements in respect to chromatic and spherical aberration, flatness of field, &c. The numerous advantages resulting from relative and absolute invariability of focus in photographic charting, in transit and meridian-circle observations, in heliometric and micrometric observations, in spectroscopic determinations of absolute wave-length and motion in the line of sight, and in fact in all work in which accuracy is of the first importance, are so readily perceived that no argument is necessary to make apparent the great desirability of so constructing our objectives as to fulfil the above conditions. The preceding examples show this to be possible within extended temperature ranges by using glasses which are easily obtainable, and which, with perhaps one possible exception, have no objectionable physical characteristics. At the same time it may be remarked that our knowledge of the thermal coefficients of expansion a_g and of refraction are less complete than they should be to secure the best results, particularly in the construction of photographic objectives. These quantities should be obtained for a larger number of the Jena glasses, and particularly for the more important varieties of Mantois glasses, concerning which we have at present no information whatever.

In work demanding the very highest degree of accuracy, the requirements in reference to knowledge of the exact focal length of the instrument at any given temperature are sometimes more severe than those imposed by the conditions in (10) and (11), which are based on considerations of visual definition only. The conditions of maximum accuracy, which have been examined

in the paper to which reference has already been made,* demand that the focal lengths be known or maintained constant to the degree of accuracy determined by the relation †

$$\delta_p = \frac{2\lambda}{a} \cdot \frac{1}{30\kappa} \quad \ldots \quad \ldots \quad \ldots \quad (15)$$

where κ is the angular field of measurement. For points very near the centre of the field, the accuracy of focus demanded by (15) is no greater than that demanded by (11), but for points at any distance from that axis the necessary accuracy is increased in the ratio

$$q = \frac{30\kappa}{\beta} \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

In a 6″ meridian circle the maximum field of measurement is only about 1′·2. Hence $30\kappa \cong \cdot 01$ and

$$q = \tfrac{1}{2}$$

i.e. the accuracy of focus necessary for good definition is more than sufficient to eliminate sensible errors of measurement due to field.

In the case of the heliometer and filar micrometer the conditions are different. Here the field measured is frequently as large as 30′. For such a case $30\kappa \cong 0{\cdot}26$ and $q \cong 6{\cdot}5$; *i.e.* the permissible change in focus is only about one-seventh as great as is allowed by considerations of visual definition alone. On this basis the total variation of focal length with temperature for a 6″ objective must not exceed

$$\frac{\Delta F}{F} = \frac{185}{6{\cdot}5} \times 10^{-6} \cong 30 \times 10^{-6},$$

or for 1° C. as before

$$\delta'_F(\text{max.}) = \frac{30 \times 10^{-6}}{\Delta T} \quad \ldots \quad \ldots \quad (17)$$

ΔT being the total range in temperature.

In spectrographic work the requirements are still more severe on account of the larger field used. For large modern spectrographs, κ may be as large as 1°·5.‡ The maximum values of a, however, do not exceed 5 cm. For these values of κ and a, δ_F becomes as before,

$$\delta_F(\text{max.}) = \frac{30 \times 10^{-6}}{\Delta T} \quad \ldots \quad \ldots \quad (18)$$

* *Astrophysical Journal*, vol. xvi. pp. 267–299; vol. xvii. pp. 1–19. 100–132.

† *Loc cit.* See equation (66).

‡ Larger fields than this are sometimes used, but, as the writer has shown at a very probable sacrifice of accuracy. *Loc. cit.* vol. xvi. pp. 281–282; vol. i. pp. 33, 110–111.

To obtain the best results in heliometric, micrometric, and spectroscopic measurements, the work must be conducted under less extreme temperature variations than have been assumed in meridian circle work. If for these observations we assume the maximum value of ΔT to be 20°, we have for δ_T(max.) for 6″ and 2″ telescopes, respectively

$$\delta'_T(\text{max.}) = 1{\cdot}5 \times 10^{-6} \quad \ldots \quad \ldots \quad (19)$$

Comparing this value of δ'_T with those obtained by combinations $(A)_v$, $(B)_v$, $(C)_v$, $(A)_p$, $(B)_p$, and $(C)_p$, we see that the conditions for heliometric and micrometric work are fully satisfied for apertures not exceeding 6″ by the visual objectives $(A)_v$ (2) in a brass tube mounting; and $(B)_v$ (1) in a steel tube mounting. The conditions for spectrographic work are similarly satisfied for linear apertures not exceeding 2″ by the photographic objectives $(A)_p$ and $(B)_p$.

Very large objectives like the 36″ Lick and the 40″ Yerkes have angular apertures considerably smaller than that assumed in computing (12) and (19). For the Yerkes 40″ $\alpha \cong 102$ cm. and $\beta \cong {\cdot}026$. Hence, for a maximum temperature range of 40°, the requirements of visual definition demand a maximum apparent change in focus not exceeding

$$\delta_T = 1 \times 10^{-6} \quad \ldots \quad \ldots \quad \ldots \quad (20)$$

For such large instruments the only possible mounting is (B), (steel tube). The condition expressed in (20) is fulfilled for only one combination, *i.e.* B_v (1). This, as already stated, is not altogether satisfactory on account of the character of the crown used. The second combination, $(B)_v$ (2), is satisfactory on this score, but has a somewhat too small coefficient of variation, δ_T.

In such cases as this we may secure *exact* compensation by constructing the tube of the telescope in two sections which are of different materials. We shall then have for each degree change in temperature

$$\frac{\delta Z}{dt} = S_1 a_1 + S_2 a_2$$

and

$$S_1 + S_2 = F.$$

For exact compensations

$$\frac{\delta F}{dt} = a'' F = S_1 a_1 + S_2 a_2$$

or

$$\frac{S_1}{F} = \frac{a'' - a_2}{a_1 - a_2} \text{ and } \frac{S_2}{F} = \frac{a'' - a_1}{a_2 - a_1} \quad \ldots \quad \ldots \quad (21)$$

For the case above considered, $a'' = 7{\cdot}9$, $a_1 = 10$, and a_2 must

therefore be smaller than a_1. If we make the section S_2 of nickel steel, $a_2 = a_n \cong 0{\cdot}2$, and we get for S_1 and S_2

$$S_1 \cong 0{\cdot}79\ F$$
$$S_2 \cong 0{\cdot}21\ F$$

i.e. about four-fifths of the tube should be of ordinary steel sheet and the remaining one-fifth of nickel steel sheet. When a'' is larger than a_1, the section S_2 must of course be made of brass, copper, or aluminium.

In the preceding examples we have endeavoured to meet the conditions of apparent invariability of focus from the standpoint, first, of visual definition, and, secondly, from that of accuracy. In the latter case there is still one further consideration which it is of importance to consider, *i.e.* the constancy of the value of one scale or screw division of the measuring or recording device. In the case of direct micrometric or heliometric measurements at the focal plane, this constancy can be secured, as we have previously shown,* by satisfying the relation

$$a' = a_t = a'' \quad \ldots \quad \ldots \quad \ldots \quad (22)$$

i.e. by making the screw or scale of material having a mean coefficient of expansion a' equal to that of the telescope tube itself. That is, we may in such cases eliminate all sensible changes in the micrometer or heliometer constants in any one of the objectives, $(A)_r$, $(B)_r$, or $(C)_r$, by making the screws or scales of these instruments of brass, steel, and nickel steel respectively.

In the case of photographic instruments we must, in order to always obtain a constant scale of record, satisfy the condition

$$a' = a_g = a'' \quad \ldots \quad \ldots \quad \ldots \quad (23)$$

and to meet this requirement, together with that of (11) or (15), we can only use one of two materials for the telescope tube, *i.e.* either steel or glass. Of these, steel is of course structurally preferable, and its coefficient, a_s, is fortunately so near the coefficient a_g that the objective $(B)_p$, whose coefficient a'' is between a_s and a_g, will, if mounted in a steel tube, have the two very desirable properties of requiring no focussing (over ranges of temperature less than 20° C),† and of yielding photographic records whose scale at any standard temperature t_o will always be the same. Such a construction is of course of the greatest value for spectrographic determinations of absolute wave length and motion in the line of sight, photographic observations for stellar

* *Loc. cit.* vol. xvii. p.

† If constancy of focus over a large range is required, it can be obtained by use of a composite tube of ordinary steel and nickel steel as already described.

parallax, and similar work in which the elimination of all small errors due to temperature variations in the apparatus itself is of fundamental importance.*

* In the case of prism spectrographs, another serious source of error is found in the temperature variations in the dispersing train. These may also be largely eliminated by proper construction of the prisms. This subject has been taken up in another paper: "Effect of Temperature Variations on the Deviation of Prism Trains and on Methods of Eliminating such Effects," now in preparation for the *Astrophysical Journal.*

Allegheny Observatory:
1902 *December.*

LIST OF WORKS
PRESENTED TO THE SOCIETY,
AND OF
WORKS PURCHASED WITH THE TURNOR AND HORROX FUND,
JUNE 1902 TO JUNE 1903.

An asterisk (*) indicates that the work is an excerpt.

Acta Mathematica. Zeitschrift, herausgegeben von G. Mittag-Leffler, Band 25, pt. 3—Band 27.
(*Turnor and Horrox Fund.*) 4to. Stockholm, 1902–1903

Aldis (W. Steadman):
*On the numerical computation of the functions $G_0(x)$, $G_1(x)$, and $J_n(x\sqrt{i})$.
(*Author.*) 8vo. London, 1899

Allegheny Observatory:
*Miscellaneous scientific papers; new series, No. 4–10. By F. L. O. Wadsworth, Director.
(*Observatory.*) 8vo. 1902–3

American Academy of Arts and Sciences: *see* Boston.

American Journal of Mathematics. Edited by T. Craig and S. Newcomb. Published under the auspices of the Johns Hopkins University. Vol. 24, No. 3—Vol. 25, No. 2.
(*Editors.*) 4to. Baltimore, 1902–1903

American Journal of Science. Editor E. S. Dana [and others]. Fourth series, Vol. 14, 15 (No. 79–90).
(*Editors.*) 8vo. New Haven, 1902–1903

Amsterdam, Koninklijke Akademie van Wetenschappen:
—— : Verhandelingen (Eerste Sectie), Deel 4; Deel 8, pt. 1, 2.
(*Academy.*) 8vo. Amsterdam, 1901–1902
Deel 4. N. M. Kam, Catalog von Sternen. Backhuyzen.
—— : Verslagen van de gewone Vergaderingen der Wis- en Natuurkundige Afdeeling, 1901–1902. Deel 10.
(*Academy.*) 8vo. Amsterdam, 1902
—— : Proceedings of the section of Sciences, vol. 4.
(*Academy.*) 8vo. Amsterdam, 1902
—— : Jaarboek, 1901.
(*Academy.*) 8vo. Amsterdam, 1902

Andoyer (H.):
Théorie de la lune.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1902

Arcetri, Reale Osservatorio:
Pubblicazioni del R. Istituto di studi superiori pratici e di perfezionamento, fasc. 16.
(*Observatory.*) 4to. Firenze, 1902
A. Abetti, Osservazioni astronomiche fatte 1901.

Arrhenius (Svante August):
Lehrbuch der kosmischen Physik.
(*Turnor and Horrox Fund.*) 2 vols. 8vo. Leipzig, 1903

Astronomical Journal. Founded by B. A. Gould [edited by S. C. Chandler]. Vol. 22, 23 (No. 522–538).
(*Editor.*) 4to. Boston, 1902–1903

Astronomische Mittheilungen. Gegründet von Rudolf Wolf: herausgegeben von A. Wolfer. No. 93.
(*Editor.*) 8vo. Zürich, 1902

Astronomische Nachrichten: Begründet von H. C. Schumacher: herausgegeben von H. Kreutz. Band 159–162 (No. 3795–3875).
(*Editor.*) 4to. Kiel, 1902–1903

—— : Astronomische Abhandlungen, als Ergänzungshefte zu den Astronomischen Nachrichten herausgegeben von H. Kreutz. No. 3, 4.
(*Editor.*) 4to. Kiel, 1902–1903
3. H. D. Curtis. Definitive determination of the orbit of Comet 1898 I.
4. M. S. de Mello e Simas. Definitive orbit elements of Comet 1900 II.
C. J. Merfield. Definitive orbit elements of Comet 1901 I.

—— : General-Register der Bände 121–150, verfasst von A. Stichtenoth; herausgegeben von H. Kreutz.
(*Turnor and Horrox Fund.*) 4to. Kiel, 1902

Astronomische Rundschau. Herausgegeben von der Manora-Sternwarte in Lussinpiccolo (Oesterreich), unter der verantwortlichen Redaction von Leo Brenner. Band 4 (Heft 37–44).
(*Turnor and Horrox Fund.*) 8vo. Altenburg, 1902–1903

Astrophysical Journal (the). An International Review of spectroscopy and astronomical physics. Edited by G. E. Hale [and others.] Vol. 15, No. 5—Vol. 17, No. 4.
(*Editors.*) 8vo. Chicago, 1902–1903

Athenæum (the). Journal of English and foreign literature, science, the fine arts, music, and the drama, 1902–1903. (No. 3894–3945.)
(*Editor.*) 4to. London, 1902–1903

Backhouse (Thomas William):
Publications of West Hendon House Observatory, Sunderland. No. 2.
(*T. W. Backhouse.*) 4to. Sunderland, 1902
The structure of the sidereal universe, Part 2. Observations of comets, zodiacal light, auroras, and variable stars.

Barnard (Edward Emerson):
——: *On the probable motion of some of the small stars in the "Dumb-bell" nebula.
(*Author.*) 8vo. London, 1902
——: *Micrometrical and visual observations of Nova Cygni (1876).
(*Author.*) 8vo. London, 1902
——: *Observations of Nova Persei 1901 with the 40-inch refractor of the Yerkes Observatory.
(*Author.*) 4to. Kiel, 1902
——: *On the change in the focus for Nova Persei.
(*Author.*) 8vo. Chicago, 1902
——: *Observations of the Aurora made at the Yerkes Observatory, 1897–1902. 8vo. Chicago, 1902
——: *Phenomena observed at the lunar eclipse, 1902 October 16.
(*Author.*) 4to. Kiel, 1903
——: *Micrometer observations of the satellite of Neptune in 1901–2 and 1902–3.
(*Author.*) 4to. Boston, 1903
——: *Diffused nebulosities in the heavens.
(*Author.*) 8vo. Chicago, 1903
——: *The South polar cap of Mars.
(*Author.*) 8vo. Chicago, 1903

Basel, Universität:
Jahresverzeichniss der schweizerischen Universitätsschriften, 1901–1902.
(*University.*) 8vo. Basel, 1902

Batavia, Koninklijke Natuurkundige Vereeniging in Nederlandsch-Indië:
Natuurkundig Tijdschrift voor Nederlandsch-Indië. Deel 61 (Serie 10, Deel 5).
(*Society.*) 8vo. Batavia, 1902

Batavia, Royal Magnetical and Meteorological Observatory:
——: Observations . . . published by order of the Government of Netherlands India. Vol. 23.
(*Observatory.*) 4to. Batavia, 1902
——: Regenwaarnemingen in Nederlandsch-Indië, Jaargang 23, 1901.
(*Observatory.*) 8vo. Batavia, 1902

Belfast Natural History and Philosophical Society:
Report and proceedings . . . for the session 1901–1902.
(*Society.*) 8vo. Belfast, 1902

Bergstrand (Östen):

*Détermination de la parallaxe annuelle de l'étoile B.D. +37°, 4131.
(*Upsala Observatory.*) 4to. Upsala, 1902

Berlin, Deutsche physikalische Gesellschaft:

——: Die Fortschritte der Physik im Jahre 1901. Jahrgang 57, dritte Abtheilung, enthaltend kosmische Physik, redigirt von Richard Assmann.
(*Society.*) 8vo. Braunschweig, 1902

——: ——————————— Namen-Register, nebst einen Sach-Ergänzungsregister zu Band 44–53, von E. und G. Schwalbe.
(*Society.*) 8vo. Braunschweig, 1903

——: Die Fortschritte der Physik im Jahre 1902–3. Halbmonatliches Litteraturverzeichniss. Jahrg. 1, No. 11–24; Jahrg. 2, No. 1–9.
(*Society.*) 8vo. Braunschweig, 1902–1903

——: Verhandlungen—Jahrgang 3, No. 11–15; Jahrg. 4, No. 1–18; Jahrg. 5, No. 1–2.
(*Society.*) 8vo. Berlin, 1901–1903

Berlin, Königlich Astronomisches Rechen-Institut:

——: Berliner Astronomisches Jahrbuch für 1905; mit Angaben für die Oppositionen der Planeten (1)–(470) für 1903. Herausgegeben . . . unter Leitung von J. Bauschinger.
(*Institute.*) 8vo. Berlin, 1903

——: Veröffentlichungen. No. 18–20.
(*Institute.*) 4to. Berlin, 1902–1903

18. J. Bauschinger [&c.]. Genäherte Oppositions-Ephemeriden von 42 kleinen Planeten, 1902–3.
19. J. Bauschinger [&c.]. Genäherte Oppositions-Ephemeriden von 36 kleinen Planeten, 1903.
20. Kleinere Arbeiten der Astronomen des Rechen-Instituts.

Berlin, Königlich Preussische Akademie der Wissenschaften:

——: Abhandlungen, 1902.
(*Academy.*) 4to. Berlin, 1902

——: Sitzungsberichte, 1902, No. 23—1903, No. 24.
(*Academy.*) 8vo. Berlin, 1902–1903

Berlin, Vereinigung von Freunden der Astronomie und Kosmischen Physik:

Mittheilungen, Jahrgang 12, Heft 6—Jahrgang 13, Heft 4.
(*Turnor and Horrox Fund.*) 8vo. Berlin, 1902–1903

Bidschof (Friedrich):

Katalog von 2417 Sternen für das mittlere Aequinoctium 1885·0, auf Grund der in den Banden 3–11 der Annalen der K. K. Universitäts-Sternwarte zu Wien enthaltenen Meridian-Beobachtungen.
(*Author.*) 4to. Wien, 1902

Bigelow (Frank H.):
Eclipse meteorology and allied problems (U.S. Department of Agriculture, Weather Bureau, Bulletin 1.)
(*F. H. Bigelow.*) 4to. Washington, 1902

Bigourdan (G.):
——: Observations de nébuleuses et d'amas stellaires. Tome 4, 5: Observations différentielles, XIV h–XXIV h.
(*Author.*) 4to. Paris, [1899, 1891]
——: *Sur la prédiction des occultations d'étoiles par la lune, et sur le calcul des longitudes terrestres au moyen des occultations, avec des tables générales de la parallaxe lunaire pour simplifier ces calculs.
(*Author.*) 4to. Paris

Birmingham Natural History and Philosophical Society:
Proceedings, Vol. 11, pt. 2.
(*Society.*) 8vo. Birmingham, 1902

Boccardi (J.):
Guide du Calculateur (Astronomie, Géodésie, Navigation, &c.)
(*Author.*) 2 parts. 4to. Paris et Catane, 1902

Bohlin (Karl):
Sur le développement des perturbations planétaires: application aux petites planètes.
(*Author.*) 4to. Stockholm, 1902

Bohren (Arnold):
Über die Fresnel'schen Integrale. Inaugural-Dissertation.
(*Berne University.*) 8vo. Bern, 1901

Boll (Franz):
Sphaera: neue griechische Texte und Untersuchungen zur Geschichte der Sternenbilder . . . mit einem Beitrag von Karl Dyroff.
(*Turnor and Horrox Fund.*) 8vo. Leipzig, 1903

Bologna, Reale Accademia delle Scienze dell' Istituto:
——: Memorie, sezione delle scienze fisiche e matematiche, Serie 5, Tomo 8.
(*Academy.*) 4to. Bologna, 1899–1900
——: Rendiconto della sessione 1899–1900, Nuova Serie, Vol. 4.
(*Academy.*) 8vo. Bologna, 1900

Bombay Branch of the Royal Asiatic Society:
Journal, Vol. 21 (No. 58).
(*Society.*) 8vo. Bombay, 1903

Bombay Government Observatory:
——: Magnetical, Meteorological, and Seismological Observations made . . . 1900–1901, under the direction of W. A. F. Moos.
(*Observatory.*) fol. Bombay, 1903
——: Report . . . 1902.
(*Observatory.*) fol. Bombay, 1903

Bonn, Königliche Sternwarte:
Veröffentlichungen . . . herausgegeben vom Direktor, Fr. Küstner. No. 6.
(*Observatory.*) 4to. Bonn, 1902
C. Mönnichmeyer und Fr. Küstner. Beobachtungen von 2294 Sternen.

Bordeaux, Société des Sciences Physiques et Naturelles:
—— : Mémoires, 6me série. Tome 1, et appendice au tome 5.
(*Society.*) 8vo. Paris et Bordeaux, 1902
—— : Procès-verbaux des séances, année 1900–1901.
(*Society.*) 8vo. Paris et Bordeaux, 1901
—— : Catalogue de la bibliothèque, 1re partie.
8vo. Bordeaux, 1901

Bossert (J.):
*Détermination des mouvements propres des étoiles; explication des discordances trouvées dans la comparaison du catalogue de Paris avec celui de Lalande. [4 Mémoires.]
(*Author.*) 4to. Paris, 1887–1902

Boston, American Academy of Arts and Sciences:
Proceedings. Vol. 37, No. 15—Vol. 38, No. 19.
(*Academy.*) 8vo. Boston, Mass., 1902–1903

Bourget (Henry):
*Eclipse totale de soleil du 28 mai 1900. Rapport de la mission organisée par l'université de Toulouse.
(*Author.*) 4to. Paris

Brédikhine (Th.):
*Sur le rôle de Jupiter dans la formation des radiants simples.
(*Author.*) 4to. St.-Pétersbourg, 1902

Brenner (Leo):
—— : *Jupiter-Beobachtungen auf der Manora Sternwarte, 1898–1901.
(*Author.*) 4to. Wien, 1902
—— : Neue Spaziergänge durch das Himmelszelt.
(*W. H. Wesley.*) 8vo. Berlin, 1903

Breslau, Königliche Universitäts-Sternwarte:
—— : Mittheilungen . . . herausgegeben von dem Direktor Julius H. G. Franz. Band 2.
(*Observatory.*) 4to. Breslau, 1903
J. Franz. Neue Methode der heliometrischen Mondmessung.
—— : Festschrift zum 90. Geburtstage des Herrn Prof. J. G. Galle.
(*University.*) 4to. Breslau, 1902

Brisbane, Royal Geographical Society of Australasia:
Queensland Geographical Journal (New Series), session 17, 1901–1902, Vol. 17.
(*Society.*) 8vo. Brisbane, 1902

British Association for the Advancement of Science:
Report of the 72nd meeting, 1902.
(*Association.*) 8vo. London, 1903

Brussels, Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique:
——: Bulletin de la classe des sciences; 1902, No. 4–12; 1903, No. 1–4.
(*Academy.*) 8vo. Bruxelles, 1902–1903
——: Mémoires, tome 54, fasc. 5.
(*Academy.*) 4to. Bruxelles, 1902
——: Mémoires couronnés et mémoires des savants étrangers. Tome 59, fasc. 3–4; tome 60; tome 62, fasc. 1, 2.
(*Academy.*) 4to. Bruxelles, 1902–1903
——: Mémoires couronnés et autres mémoires. (Collection in 8vo.) Tome 56; tome 62, fasc. 1–4; tome 63, fasc. 1–3.
(*Academy.*) 8vo. Bruxelles, 1896, 1902–1903
——: Annuaire, année 69.
(*Academy.*) 8vo. Bruxelles, 1903

Brussels, Société Belge d'Astronomie:
——: Bulletin . . . Comptes rendus des séances mensuelles de la Société, et revue des sciences d'observation: astronomie, météorologie, géodésie et physique du globe. Anné 1–8, No. 5. 8vo. Bruxelles, 1895–1903
——: Mémoires . . . Section des étoiles filantes.
(*Society.*) 4to. Bruxelles
G. Barone. La grande pluie météorique de novembre 1899.
——: Annuaire pour l'an 1903 . . . Guide de l'amateur astronome et météorologiste. Année 8.
(*Society.*) 8vo. Bruxelles, 1903

Budapest, Königl. Ungarische Reichsanstalt für Meteorologie und Erdmagnetismus:
——: Bericht über die Thätigkeit der Kgl. ung. Reichsanstalt . . . und des Central-Observatoriums in O-Gyalla im Jahre 1901.
(*Institute.*) 8vo. Budapest, 1902
——: Jahrbücher. Jahrgang 1898–1901, Band 29, Theil 3; 30, 1, 3; 31, 2.
(*Institute.*) 4to. Budapest, 1901–1902
——: Namen- und Sach- register der Bibliothek.
(*Institute.*) 8vo. Budapest, 1902
——: Publicationen, 1902. Band 5.
(*Institute.*) 4to. Budapest, 1902

Budapest, Magyar Tudományos Akadémia:
——: Almanach, 1902.
(*Academy.*) 8vo. Budapest, 1902
——: Mathematikai és természettudományi Értesitö. Kotet 19, 3–5.
(*Academy.*) 8vo. Budapest, 1901–1902

Budapest, Magyar Tudományos Akadémia—*continued.*

—— : Mathematikai és természettudományi Közlemények. Kotet 28, 1.
(*Academy.*) 8vo. Budapest, 1902

—— : Mathematische und naturwissenschaftliche Berichte aus Ungarn. Band 17.
(*Academy.*) 8vo. Berlin und Budapest, 1901

—— : Rapport sur les travaux de l'Académie hongroise des Sciences en 1901, par C. Szily.
(*Academy.*) 8vo. Budapest, 1902

Bulletin Astronomique. Fondé en 1894 par E. Mouchez et F. Tisserand. Publié par l'Observatoire de Paris. Tome 19, No. 7—Tome 20, No. 6.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1902–1903

Bulletin des Sciences Mathématiques. Rédigé par G. Darboux et J. Tannery. Série 2. 1902–1903, Tome 26, No. 5—Tome 27, No. 5.
(*Editors.*) 8vo. Paris, 1902–1903

Bushey, National Physical Laboratory :
Report for the year 1902.
(*Laboratory.*) 8vo. London, 1903

Calcutta, Asiatic Society of Bengal :

—— : Journal, Part II ; Vol. 70, No. 2—Vol. 71, No. 3. Part III ; Vol. 70, No. 2—Vol. 71, No. 2.
(*Society.*) 8vo. Calcutta, 1901–1902

—— : Proceedings, 1901, No. 9–11 ; 1902, No. 1–10.
(*Society.*) 8vo. Calcutta, 1901–1903

Cambridge Philosophical Society :

—— : Proceedings, Vol. 11, pt. 6, 7 ; Vol. 12, pt. 1, 2.
(*Society.*) 8vo. Cambridge, 1902–1903

—— : Transactions, Vol. 19, pt. 2.
(*Society.*) 8vo. Cambridge, 1902

Canada, Department of Marine [&c.] :
Report of the Meteorological Service of Canada, by R. F. Stupart, Director. 1899, 1900.
(*Department.*) 4to. Ottawa, 1902

Canada, Royal Society :
Proceedings and Transactions. Second series. Vol. 7, 1901.
(*Society.*) 8vo. Ottawa [Montreal], 1901

Cape of Good Hope, Geodetic Survey of South Africa :
Vol. 2. Report on a discussion of Bailey's and Fourcade's surveys, and their reduction to the system of the Geodetic Survey. By Sir D. Gill.
(*Office.*) fol. Cape Town, 1902

Cape of Good Hope, Royal Observatory :

—— : Independent day numbers for the year 1904.
(*Observatory.*) 8vo. London, 1901

—— : Report of H.M. Astronomer . . . for the year 1901.
(*Observatory.*) 4to. London, 1902

Cape Town, South African Philosophical Society:
Transactions, 1900. Vol. 11, pt. 4; Vol. 12, pt. 2.
(*Society.*) 8vo. Cape Town, 1902

Cardiff, Astronomical Society of Wales:
The Cambrian Natural Observer. New series. Vol. 5.
(*Society.*) 16mo. Cardiff, 1903.

Catania, Società degli Spettroscopisti Italiani:
Memorie . . . raccolte e pubblicate per cura del Prof. A. Riccò. Vol. 31, No. 5—Vol. 32, No. 5.
(*Society.*) 4to. Catania, 1902–1903

Charlier (Carl Ludwig):
Die Mechanik des Himmels: Vorlesungen. Band 1.
(*Turnor and Horrox Fund.*) 8vo. Leipzig, 1902

Cherbourg, Société Nationale des Sciences naturelles et mathématiques:
Mémoires. Tome 32, 33 (4me série, tome 2, 3).
(*Society.*) 8vo. Paris et Cherbourg, 1901–1902

Chicago Academy of Sciences:
Bulletin, Vol. 2, No. 3; and No. 4 (pt. 1 of the Natural History Survey).
(*Academy.*) 8vo. Chicago, 1900

Ciel et Terre. Revue populaire d'astronomie, de météorologie et de physique du globe. Année 23, no. 8—Année 24, no. 7.
(*Turnor and Horrox Fund.*) 8vo. Bruxelles, 1902–1903

Clerke (Agnes M.):
——: A popular history of Astronomy during the nineteenth century . . . fourth edition.
(*A. and C. Black.*) 8vo. London, 1902
——: Problems in Astrophysics.
(*Author.*) 8vo. London, 1903

Comstock (George C.):
A text-book of Astronomy.
(*Turnor and Horrox Fund.*) 8vo. London and N. York, 1901

Copenhagen, Kongelige Danske Videnskabernes Selskab:
——: Oversigt over det K. Danske Videnskabernes Selskabs Forhandlinger. 1902, No. 2–6; 1903, No. 1.
(*Society.*) 8vo. Kjöbenhavn, 1902–1903
——: Skrifter, naturvidensk. og mathematisk Afd. 6te Række, Bd. 10, No. 4: Bd. 11, No. 2–4: Bd. 12, No. 1, 2.
(*Society.*) 4to. Kjöbenhavn, 1902

Cordoba, Oficina Meteorológica Argentina:
Anales . . . por su Director G. G. Davis. Tomo 14.
(*The Office.*) 4to. Buenos Aires, 1901

Crace (J. D.):
* Francis Cramer Penrose: a memoir.
(*Author.*) 4to. London, 1903

Cracow, Académie des Sciences:

—— : Bulletin International: Comptes rendus des séances, 1902, No. 5—1903, No. 3.
(*Academy.*) 8vo. Cracovie, 1902–1903

—— : Catalogue of the Polish scientific literature. Tom. 2, No. 1–3.
(*Academy.*) 8vo. Kraków, 1902–1903

Crommelin (Andrew C. D.):

* An adaptation of Major Grant's graphical method of predicting occultations to the elements now given in the *Nautical Almanac.*
(*Author.*) 8vo. London, 1902

Dijon, Académie des Sciences, Arts et Belles-lettres:

Mémoires, 4me série, tome 8.
(*Academy.*) 8vo. Dijon, 1903

Dinwiddie (W. Walter):

* A device for conducting electric circuits to the eye end of an equatorial telescope.
(*Author.*) 8vo. Northfield, Minn., 1902

Donitch (M. W.):

—— : * Observations de l'éclipse totale du soleil du 28 mai 1900 à Elche, près d'Alicante (Espagne).
(*Author.*) 4to. St.-Pétersbourg, 1901

—— : * Sur l'état des enveloppes du soleil à l'époque du dernier minimum de son activité.
(*Author.*) 4to. St.-Pétersbourg, 1903

Doolittle (Charles L.):

* Results of Observations with the zenith telescope of the Sayre Observatory from April 1, 1876, to December 27, 1893.
(*Author.*) 4to. Philadelphia, 1902

Dublin, Royal Irish Academy:

—— : Proceedings, third series, Vol. 6, No. 4; Vol. 24 (Section A), pt. 1.
(*Academy.*) 8vo. Dublin, 1902

—— : Transactions, Vol. 31, part 7, 12; Vol. 32 (Section A), pt. 1–5.
(*Academy.*) 4to. Dublin, 1902

Dublin, Royal Society:

—— : Scientific proceedings. New series. Vol. 9, pt. 5.
(*Society.*) 8vo. Dublin, 1903

—— : Scientific transactions. Series II. Vol. 7, pt. 14–16; Vol. 8, pt. 1.
(*Society.*) 4to. Dublin, 1902

Dunér (Nils Christian):

Tal vid K. Vetenskaps-Akademiens Minnesfest den 24 Oktober, 1901; trehundraårsdagen af Tycho Brahes död.
(*R. Acad., Stockholm.*) 8vo. Stockholm, 1901

Dünner (Lasar):
Die aelteste astronomische Schrift des Maimonides. . . . Ein Beitrag zur Geschichte der Astronomie.
(*Turnor and Horrox Fund.*) 8vo. Würzburg, 1902

Edinburgh, Royal Society:
—— : Proceedings, 1899–1900. Vol. 23.
(*Society.*) 8vo. Edinburgh, 1901
—— : Transactions, 1900–1902. Vol. 40, pt. 1, 2; Vol. 42. (Ben Nevis Observations.)
(*Society.*) 4to. Edinburgh, 1901–1902

Egypt, Survey Department:
Meteorological Observations:—
—— : Abbassia, Cairo, April 1902 to March 1903.
—— : Alexandria, April 1902 to March 1903.
—— : Assiut, April 1902 to February 1903.
—— : Aswan, March 1902 to March 1903.
—— : Berber, March 1902 to January 1903.
—— : Duem, March 1902 to January 1903.
—— : Giza, March 1902 to January 1903.
—— : Halfa, February 1902 to January 1903.
—— : Khartum, July 1902 to February 1903.
—— : Omdurman, February 1902 to June 1902.
—— : Port Saïd, March 1902 to February 1903.
—— : Suakin, March 1902 to January 1903.
—— : Wad Medani, March 1902 to January 1903.
(*Survey Department, Egypt.*) fol. 1902–1903

English Mechanic (the) and World of Science:
Vol. 75–77 (No. 1943–1994).
(*Editor.*) fol. London, 1902–1903

Espin (T. H. E. C.):
A possible factor in volcanic eruptions. (Publications of the Wolsingham Observatory.)
(*Author.*) 8vo. Crook, 1902

Evans (H. B.):
The mean Right Ascensions and Proper Motions of 254 stars. [University Thesis.]
(*Author.*) 4to. [Philadelphia, 1902]

Exner (Franz), und E. Haschek:
Wellenlängen-Tabellen für spektralanalytische Untersuchungen, auf Grund der ultravioletten Funkenspektren der Elemente.
(*Turnor and Horrox Fund.*) 2 parts, 8vo. Leipzig und Wien, 1902

Faye (Hervé Aug. Et.):
Eloges, *see* Bouquet de la Grye, M. Lœwy.

Flammarion (Camille):
Annuaire astronomique et météorologique pour 1903.
(*Editor.*) 8vo. Paris, 1902

Galilei (Galileo):
Opere . . . Edizione Nazionale, sotto gli auspicii di Sua Maestà il Re d' Italia. Vol. 12.
(*Italian Government.*) 4to. Firenze, 1902

Geneva, Observatoire:
——: *Observations météorologiques faites aux fortifications de Saint-Maurice pendant l'année 1901. Résumé par R. Gautier.
(*Author.*) 8vo. Genève, 1902
——: *Résumé météorologique . . . pour Genève et le Grand Saint-Bernard, par R. Gautier, 1901.
(*Observatory.*) 8vo. Genève, 1902

Geneva, Société de physique et d'histoire naturelle:
Mémoires, tome 34, fasc. 2, 3.
(*Society.*) 4to. Genève, 1902–1903

Georgetown College Observatory:
——: Chart and Catalogue for observing Nova Geminorum. By J. G. Hagen.
(*Observatory.*) 4to. Georgetown, 1903
——: Observations of variable stars made in the years 1884–1890. Part 1. The Observations. J. G. Hagen, Director.
(*Observatory.*) 4to. Washington, 1901

Göttingen, Königliche Gesellschaft der Wissenschaften:
Nachrichten, mathematisch-physikalische Klasse.
1902, Heft 2–6; 1903, Heft 1, 2.
(*Society.*) 8vo. Göttingen, 1902–1903

Greenwich, Royal Observatory:
Report of the Astronomer Royal to the Board of Visitors . . . 1903.
(*Observatory.*) 4to. London, 1903

Griesbach (J. Henry):
Figures of the solar spots from July 1850 [to April 1865], as seen with a Newtonian reflecting telescope, its mirror 6 inches diameter and focal length 6 feet. [Original drawings.]
(*Henry Eichbaum.*) 4to.

Haasemann (L.):
*Der Pendelapparat für relative Schwerenmessungen der deutschen Südpolarexpedition.
(*Author.*) 4to. Berlin, 1902

Hadden (David E.):
*The Solar Surface during the past twelve years. A review of Sun-spot observations made at Alta, Iowa, from 1890 to 1902.
(*Author.*) 8vo. Des Moines, 1903

Halifax, Nova Scotian Institute of Science:
Proceedings and Transactions. Vol. 10 (Second Series, Vol. 3), pt. 3, 1900–1901.
(*Institute.*) 8vo. Halifax, 1902

Hartwig (Ernst): . . .
*Ephemeriden veränderlicher Sterne für 1903.
(*Author.*) 8vo. Leipzig, 1902

Harvard College Astronomical Observatory:
—— : Annals, Vol. 37, pt. 2; Vol. 38; Vol. 41, No. 8 and 9; Vol. 43, pt. 2; Vol. 44, pt. 2; Vol. 48, No. 2 and 4.
(*Observatory.*) 4to. Cambridge, Mass., 1902–1903

Vol. 37, pt. 2. O. C. Wendell. Observations of 58 variable stars of long period . . . during 1890–1901.
„ 38. S. I. Bailey. Variable stars in the cluster ω Centauri.
„ 41, No. 8. W. Doberck. Magnitudes of 923 fixed stars.
„ „ „ 9. E. S. King. Absorption of photographic wedges.
„ 43, pt. 2. A. L. Rotch. Blue Hill Meteorological Observations.
„ 44, „ 2. E. C. Pickering. Reduction of observations made with the Meridian Photometer, 1892–1898.
„ 48, No. 2. Observations of the light of *Nova Persei*, No. 2.
„ „ „ 4. Catalogue of 1520 bright stars.

—— : Circular, No. 66–71.
(*Observatory.*) 4to. Cambridge, Mass., 1902–1903
—— : Fifty-seventh annual report of the Director . . . 1901–1902. By E. C. Pickering.
(*Observatory.*) 8vo. Cambridge, Mass., 1902

Hasselberg (B.):
*Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. VI. Spectrum des Molybdäns.
(*Author.*) 4to. Stockholm, 1902

Heath (Thomas):
The twentieth-century Atlas of popular Astronomy, comprising in twenty-two plates a complete series of illustrations of the heavenly bodies.
(*Turnor and Horrox Fund.*) 4to. Edinburgh, 1903

Heidelberg (Königstuhl), Astrophysikalisches Observatorium:
Publikationen . . . Band 1. Herausgegeben von Max Wolf.
(*Observatory.*) 4to. Karlsruhe, 1902

Hill (George William):
*Illustrations of periodic solutions in the Problem of Three Bodies.
(*Author.*) 4to. Boston, Mass., 1902

Himmel und Erde. Illustrierte naturwissenschaftliche Monatsschrift, herausgegeben von der Gesellschaft Urania; Redacteur P. Schwahn. Jahrgang 14, Heft 9—Jahrgang 15, Heft 8.
(*Editor.*) 8vo. Berlin, 1902–1903

Hobart, Royal Society of Tasmania:
Papers and Proceedings, 1900-1901.
(*Society.*) 8vo. Hobart, 1902

Hong Kong Observatory:
Observations made . . . in the year 1901, by W. Doberck.
(*Observatory.*) fol. Hong Kong, 1902

Horological Journal (the):
Vol. 44, 45 (No. 527-538).
(*Brit. Horol. Institute.*) 8vo. London, 1902-1903

India, Survey Department:
——: Account of the operations of the Great Trigonometrical Survey of India. Vol. 16 . . . prepared under the direction of Major S. G. Burrard.
(*H.M. Govt. in India.*) 4to. Dehra Dûn, 1901
Tidal Observations, 1873-92.
——: General report on the operations of the Survey of India Department . . . during 1900-1901.
(*H.M. Govt. in India.*) fol. Calcutta, 1902
——: Professional Papers, No. 6.
(*H.M. Govt. in India.*) 4to. Dehra Dûn, 1902
F. B. Longe. Determination of the coefficients of expansion of the wires of the Jäderin Base-line apparatus.

Indian Engineering:
An illustrated weekly journal, edited by Pat. Doyle. Vol. 31, No. 21—Vol. 33, No. 20.
(*Editor.*) fol. Calcutta, 1902-1903

International Catalogue of Scientific Literature:
Vol. 4, part 1. Physics, pt. 1 (to Feb. 1902). Vol. 4, part 2. Physics, pt. 2 (to Oct. 1902). Vol. 5. Astronomy (to May 1902).
(*Turnor and Horrox Fund.*) 8vo. London, 1902

Jecklin (Lucius):
Historisch-kritische Untersuchung über die Theorie der hypergeometrischen Reihe bis zu den Entdeckungen von E. E. Kummer. Inaugural-Dissertation.
(*Berne University.*) 8vo. Schiers, 1901

Kam (N. M.):
*Catalog von Sternen, deren Oerter durch selbstständige Meridian-Beobachtungen bestimmt worden sind aus Band 67 bis 112 der *Astronomischen Nachrichten*, reducirt auf 1875·0 . . . herausgegeben von H. G. van de Sande Backhuyzen. (Verhand. K. Akad. Amsterdam, Deel 4.)
(*Academy.*) 4to. Amsterdam, 1902

Kasan, Imperial University:
Uchenuiya Zapiski. 1902, No. 4-7, 9-12; 1903, No. 1-4.
(*University.*) 8vo. Kasan, 1902-1903

Kayser (H.):
Handbuch der Spectroscopie. Band 2.
(*Turnor and Horrox Fund.*) 8vo. Leipzig, 1902

Klein (Hermann J.):
Jahrbuch für Astronomie und Geophysik. Jahrgang 12, 13, 1901–1902.
(*Turnor and Horrox Fund.*) 8vo. Leipzig, 1902–1903

Knowledge. An illustrated magazine of science, literature, and art. Vol. 25, 26 (No. 201–212).
(*Turnor and Horrox Fund.*) 4to. London, 1902–1903

Kramer (Julius):
*Theorie der kleinen Planeten: die Planeten vom Hecuba-Typus.
(*Turnor and Horrox Fund.*) 4to. Berlin, 1902

Krisch (August):
Astronomisches Lexikon, auf Grundlage der neuesten Forschungen, besonders der Ergebnisse der Spectralanalyse und der Himmelsphotographie.
(*Turnor and Horrox Fund.*) 8vo. Wien, 1902

Kummer (M.):
Darlegung Weber'schen und verwandter Integrale: ihre Theorie und Anwendung. Inaugural-Dissertation.
(*Berne University.*) 8vo. Bern, 1902

Leeds Astronomical Society:
Journal and Transactions, 1901–1902. (No. 9, 10.)
(*Society.*) 8vo. Leeds, 1902–1903

Leeds Philosophical and Literary Society:
82nd Annual Report, 1901–1902.
(*Society.*) 8vo. Leeds, 1902

Leiden, Sterrenwacht:
——: Annalen, . . . herausgegeben von H. G. van de Sande Backhuyzen. Band 8.
(*Observatory.*) 4to. Haag, 1902
——: Verslag van den Staat der Sterrenwacht te Leiden, 1900–1902.
(*Observatory.*) 8vo. Leiden, 1902
——: Catalogus van de boeken aanwezig in de Bibliotheek . . . Vierde Supplement.
(*Observatory.*) 8vo. 's Gravenhage, 1902

Leipzig, Astronomische Gesellschaft:
——: Catalog der Astronomischen Gesellschaft; erste Abtheilung; Catalog der Sterne bis zur neunten Grösse zwischen 80° nördlicher und 2° südlicher Declination für das Æquinoctium 1875. Stück 8.
(*Society.*) 4to. Leipzig, 1902
Zone +30° bis +35°. (Leiden.)

Leipzig, Astronomische Gesellschaft—*continued.*

——: Vierteljahrsschrift, Jahrgang 37, Heft 1–4; Jahrg. 38, Heft 1, 2.
(*Society.*) 8vo. Leipzig, 1902–1903

Leipzig, Fürstlich Jablonowski'sche Gesellschaft:
Jahresbericht, 1903.
(*Society.*) 8vo. Leipzig, 1903

Leipzig, Königlich Sächsische Gesellschaft der Wissenschaften:

——: Abhandlungen, mathematisch-physische Classe. Band 27, No. 4–9. Band 28, No. 1–3.
(*Society.*) 8vo. Leipzig, 1902–1903

——: Berichte über die Verhandlungen: mathematisch-physische Classe, 1900. Band 53, Heft 7; 54, Heft 1–7; 55, Heft 1, 2.
(*Society.*) 8vo. Leipzig, 1902–1903

Lick Observatory, University of California:
Bulletin, No. 19–35.
(*Observatory.*) 4to. 1902–1903

Liverpool Literary and Philosophical Society:
Proceedings . . . No. 56 (1901–1902).
(*Society.*) 8vo. Liverpool, 1902

Liverpool Observatory:
Report of the director of the observatory to the Marine Committee, and meteorological results . . . 1901.
(*Observatory.*) 8vo. Liverpool, 1902

Lockyer (Norman) and W. J. S. Lockyer:
*On some phenomena which suggest a short period of solar and meteorological changes.
(*Solar Physics Observatory.*) 8vo. London, 1902

——: *On the similarity of the short-period pressure variation over large areas.
(*Solar Physics Observatory.*) 8vo. London, 1903

——: *The relation between solar prominences and terrestrial magnetism.
(*Solar Physics Observatory.*) 8vo. London, 1903

Loewy (Maurice):

——: *Sur le grand équatorial coudé de l'Observatoire de Paris.
(*Author.*) 4to. Paris, 1894

——: *Recherches nouvelles sur la détermination absolue des coordonnées équatoriales des étoiles et de la latitude: développement des formules.
(*Author.*) 4to. Paris, 1898

——: *Sur la précision des mesures des coordonnées rectilignes des images stellaires. [3 mémoires.]
(*Author.*) 4to. Paris, 1901

——: Discours prononcé aux funérailles de M. Faye.
(*Author.*) 4to. Paris, 1902

Loewy (Maurice) et P. Puiseux:

——: *Théorie du système optique composé d'une lunette astronomique et d'un double miroir plan. Application à la mesure précise des distances en vue de l'étude de l'aberration et de la réfraction.
(*M. Loewy.*) 4to. Paris, 1891

——: *Sur les photographies de la lune obtenues au grand equatorial coudé de l'Observatoire de Paris, &c. [5 memoirs referring to the Paris Photographic Atlas of the Moon.]
(*M. Loewy.*) 4to. Paris, 1894–1902

——: *Sur la constitution physique de la lune et l'interprétation de divers traits de sa surface mis en évidence par la photographie.
(*M. Loewy.*) 4to. Paris, 1895

London, British Astronomical Association:

——: Journal, Vol. 12, No. 8—Vol. 13, No. 7.
(*Association.*) 8vo. London, 1902–1903

——: Memoirs, Vol. 10, pt. 3, 4; Vol. 11, pt. 2; Vol. 12, pt. 1.
(*Association.*) 8vo. London, 1902–1903

——: List of members, 1902. 8vo. London, 1902

London, Camera Club:

Journal, Vol. 16–17 (No. 193–204).
(*The Club.*) 4to. London, 1902–1903

London, Geological Society:

——: Quarterly Journal, Vol. 58, pt. 3—Vol. 59, pt. 2 (No. 231–234).
(*Society.*) 8vo. London, 1902–1903

——: Geological literature added to the . . . Library, 1901, 1902.
(*Society.*) 8vo. London, 1902–1903

London, Meteorological Office:

——: Hourly means of the readings obtained from the self-recording instruments at the five Observatories under the Meteorological Council, 1899.
(*The Office.*) 4to. London, 1902

——: Meteorological Observations at stations of the second order for the year 1899.
(*The Office.*) 4to. London, 1902

——: Temperature tables for the British Islands; supplement. Difference tables for each five years for the extrapolation of mean values.
(*The Office.*) 4to. London, 1902

——: Weekly weather report, Vol. 19, No. 24—Vol. 20, No. 21.
(*The Office.*) 4to. London, 1902–1903

London, Nautical Almanac and Astronomical Ephemeris for the meridian of the Royal Observatory, Greenwich. 1906.
(*Lords Commissioners of Admiralty.*) 8vo. London, 1903

—— : Ditto, Part 1 ; containing such portions as are essential for navigation, 1906.
(*Lords Commissioners of Admiralty.*) 8vo. London, 1903

—— : Appendix to the Nautical Almanac, 1903. Corrections to the apparent places of Nautical Almanac stars, visible at Greenwich.
(*Lords Commissioners of Admiralty.*) 8vo. London, 1902

London, Physical Society:
Proceedings, Vol. 18, pt. 2–4.
(*Society.*) 8vo. London, 1902–1903

London, Royal Geographical Society:
The Geographical Journal, including the Proceedings of the Royal Geographical Society. Vol. 20, 21.
(*Society.*) 8vo. London, 1902–1903

London, Royal Institution:
Proceedings, 1900. Vol. 16, pt. 3 (No. 95).
(*Institution.*) 8vo. London, 1902

London, Royal Meteorological Society:

—— : Quarterly Journal, Vol. 28, 29 (No. 123–126).
(*Society.*) 8vo. London, 1902–1903

—— : The Meteorological Record: Monthly results of observations made at the stations of the Royal Meteorological Society, with remarks on the weather . . . by W. Marriott. Vol. 21, 22 (No. 84–87).
(*Society.*) 8vo. London, 1902–1903

London, Royal Photographic Society:
The Photographic Journal ; including the Transactions of the Royal Photographic Society, Vol. 26, No. 5–11 ; Vol. 43 (Whole series), No. 1–4.
(*Society.*) 8vo. London, 1902–1903

London, Royal Society:

—— : Proceedings, Vol. 70–71 (No. 461–476).
(*Society.*) 8vo. London, 1902–1903

—— : Report of the Meteorological Council for the year ending 31st March, 1902.
(*Meteorological Office.*) 8vo. London, 1902

—— : Year-book of the Royal Society of London, 1903.
(*Society.*) 8vo. London, 1903

London, Royal United Service Institution :
Journal, Vol. 46, 47 (No. 291–303).
(*Institution.*) 8vo. London, 1902–1903

London, Society of Arts:
Journal, Vol. 50, 51 (No. 2586–2637).
(*Society.*) 8vo. London, 1902–1903

London, Solar Physics Observatory:
——: The Sun's spotted area, 1832–1900. A statement of the mean daily area in each synodic rotation of the Sun, based upon data collected at the Solar Physics Observatory, South Kensington.
(*Observatory.*) 4to. London, 1902
——: Report made to the Solar Physics Committee . . . 1900–1902 by Sir Norman Lockyer.
(*Observatory.*) 8vo. London, 1902

London, University College:
Calendar, session 1902–1903.
(*The College.*) 8vo. London, 1902

Madrid Observatorio Astronómico:
Resumen de las observaciones meteorológicas efectuadas en la Península [&c.] 1897–98.
(*Observatory.*) 8vo. Madrid, 1902

Manchester Literary and Philosophical Society:
Memoirs and Proceedings, Vol. 46, pt. 6—Vol. 47, pt. 4.
(*Society.*) 8vo. Manchester, 1902–1903

Manila, Observatorio:
Boletín Mensual. Año 1901, trimestre 3, 4.
(*Observatory.*) 4to. Manila, 1902

Manila, Philippine Weather Bureau:
——: Monthly Bulletins. 1902 Sept.–Nov.
(*Bureau.*) 4to. Manila, 1902–1903
——: Report of the Director, 1901–1902. Part 1. The climate of Baguio, by J. Algué.
(*Bureau.*) 4to. Manila, 1903

Maunder (E. Walter):
Astronomy without a telescope: a guide to the Constellations, and introduction to the study of the heavens with the unassisted sight.
(*Messrs. Witherby & Co.*) 8vo. London [1902]

Mauritius Meteorological Society:
Proceedings and Transactions. New series. Vol. 2.
(*Society.*) 8vo. Mauritius, 1902

Melbourne Observatory:
——: Results of observations in meteorology and terrestrial magnetism, . . . 1901 July–Dec., under the direction of P. Baracchi.
(*Observatory.*) 8vo. Melbourne, 1902
——: Thirty-sixth Report of the Board of Visitors, . . . together with the report of the Government Astronomer, 1901–1902.
(*Observatory.*) fol. Melbourne, 1902

Miranda y Marron (Manuel):
Le cycle d'activité solaire et l'essaim des Léonides.
(*Soc. Astron. de Mexico.*) 8vo. Mexico, 1903

Moncalieri, Osservatorio Centrale del Real Collegio Carlo Alberto:
Bollettino mensuale (Società Meteorologica Italiana). Serie 2, Vol. 22, No. 1–6.
(*Observatory.*) 4to. Torino, 1902

Montpellier, Académie des Sciences et Lettres:
Mémoires de la section des sciences. 2me série, tome 3, no. 2.
(*Academy.*) 8vo. Montpellier, 1902

Moscow, Observatoire Astronomique:
Annales . . . publiées sous la rédaction de W. Ceraski. Deuxième série, vol. 4.
(*Observatory.*) 4to. Moscou, 1902

Moscow, Société Impériale des Naturalistes:
Bulletin, année 1901, no. 3, 4; 1902, no. 3.
(*Society.*) 8vo. Moscou, 1902

Munich, Königlich bayerische Akademie der Wissenschaften:
——: Abhandlungen der mathematisch-physikalischen Classe. Band 21, Abth. 3.
(*Academy.*) 4to. München, 1902
——: Sitzungsberichte der mathematisch-physikalischen Classe. 1902, Heft 2–3; 1903, Heft 1.
(*Academy.*) 8vo. München, 1902–1903

Naegamvala (Kavasji Dadabhai):
Report of the total solar eclipse of 1898 January 21–22, as observed at Jeur, in Western India. (Publications of the Maharaja Takhtasingji Observatory, Poona, Vol. 1.)
(*Observatory.*) 4to. Bombay, 1902

Naples, Società Reale (R. Accademia delle Scienze):
——: Atti, serie seconda, vol. 11.
(*Academy.*) 4to. Napoli, 1902
——: Rendiconto dell' Accademia delle scienze fisiche e matematiche: serie 3, vol. 8, fasc. 4–12; vol. 9, fasc. 1–4. (Anno 41, 42.)
(*Academy.*) 8vo. Napoli, 1902–1903

Natal Observatory:
Report of the Government Astronomer for the year 1901.
(*Observatory.*) fol. Pietermaritzburg, 1902

Nature. A weekly illustrated journal of science, Vol. 66–68 (No. 1703–1754).
(*Turnor and Horrox Fund.*) 4to. London, 1902–1903

Naturwissenschaftliche Rundschau. Wöchentlicher Bericht über die Fortschritte auf dem Gesammtgebiete der Naturwissenschaften . . . herausgegeben von W. Sklarek. Jahrgang 17, No. 25–52; Jahrgang 18, No. 1–23.
(*Editor.*) 4to. Braunschweig, 1902–1903

Nau (F.):
*Le traité sur l'Astrolabe plan de Sévère Sabokt, écrit au VII^e siècle d'après des sources grecques, et publié pour la première fois avec traduction française.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1899

New Haven, Connecticut Academy of Arts and Sciences:
Transactions, Vol. 11, pt. 1, 2.
(*Academy.*) 8vo. New Haven, 1901–1903

Newkirk (Burt L.):
Eine Untersuchung der Parallaxe des Zentralsternes des Ringnebels in der Leier. [Inaugural-Dissertation.]
(*Author.*) 8vo. München, 1902

Northfield, Minn., Carleton College:
Publications of the Goodsell Observatory, No. 2, 3 . . . under the direction of W. W. Payne.
(*Observatory.*) 8vo. Northfield, Minn., 1901
2. Longitude determinations.
3. Observations of sunspots and measures of solar photographs.

Observatory (The). A monthly review of astronomy; edited by T. Lewis and H. P. Hollis, Vol. 25, 26 (No. 320–332).
(*Editors.*) 8vo. London, 1902–1903

O-Gyalla, Königl. ung. meteorologisch-magnetisches Central-Observatorium:
Beobachtungen angestellt April 1902–April 1903.
(*Observatory.*) 4to. Budapest, 1902–1903
See also Budapest.

Oudemans (J. A. C.) et J. Bosscha:
*Galilée et Marius.
(*Authors.*) 8vo. Harlem, 1903

Oxford University Observatory:
——: Twenty-eighth Annual Report of the Savilian Professor for 1902–1903.
(*Observatory.*) 8vo. Oxford, 1903
——: *Miscellaneous papers . . . edited by H. H. Turner, Vol. 1. 8vo. Oxford, 1902

Pannekoek (Ant.):
Untersuchungen über den Lichtwechsel Algols.
(*Author.*) 8vo. Leiden, 1902

Paris, Académie des Sciences:
Comptes rendus hebdomadaires des séances. Tome 134, no. 23—tome 136, no. 22.
(*Academy.*) 4to. Paris, 1902–1903

Paris, Bureau des Longitudes:
——: Annuaire pour l'an 1903; avec des notices scientifiques.
(*Bureau.*) 16mo. Paris, [1902]
——: Connaissance des Temps, ou des mouvements célestes pour le méridien de Paris, à l'usage des astronomes et des navigateurs, 1905.
(*Bureau.*) 8vo. Paris, 1902

Paris, Bureau des Longitudes—*continued.*

—— : Connaissance des Temps. Extrait à l'usage des Écoles d'Hydrographie et des marins du commerce, 1903, 1904. (*Bureau.*) 8vo. Paris, 1901–1902

—— : Éphémérides des étoiles de culmination lunaire et de longitude, pour 1903–1904. Par M. Loewy. (*Bureau.*) 4to. Paris, 1901–1902

Paris, Bureau International des Poids et Mesures :

—— : Procès-verbaux des séances [du comité] de 1901. (*Bureau.*) 8vo. Paris, 1901

—— : Travaux et mémoires. Tome 10. (*Bureau.*) 4to. Paris, 1902

Paris, Congrès Astrophotographique International :

—— : Carte photographique du ciel. Zone $-1°$, $+2°$, $+3°$, $+5°$, $+7°$, $+9°$, $+16°$, $+20°$, $+22°$, $+24°$. (Alger, Toulouse, Bordeaux, Paris.) 93 charts. (*The Minister of Public Instruction.*)

—— : Conférence astrophotographique internationale de juillet, circulaire, no. 1–10. (*Académie des Sciences.*) 4to. Paris, 1900–1903

Paris, Dépôt Général de la Marine :

Annales hydrographiques. Série 2. Année 1902. (*Depôt of Marine.*) 8vo. Paris, 1902

Paris, École Polytechnique :

Journal. Série 2, cahier 7. (*École Polytechnique.*) 4to. Paris, 1902

Paris, Observatoire :

—— : Annales . . . publiées sous la direction de M. Loewy. Mémoires, tome 23. (*Observatory.*) 4to. Paris, 1902

H. Andoyer, Extension du théorème de Poisson ; J. Mascart, Étude des planètes télescopiques ; A. Lebeuf, Polynomes Hansen-Tisserand ; O. Callandreau, Théorie des comètes périodiques ; G. Bigourdan, Prédiction des occultations d'étoiles ; J. Mascart, L'anneau des petites planètes ; O. Callandreau, Détermination des orbites des comètes et des planètes.

—— : Atlas photographique de la lune . . . exécuté par M. Loewy et P. Puiseux. Fasc. 6. (*Observatory.*) fol. (text in-4to.), Paris, 1902

—— : Catalogue de l'Observatoire de Paris : étoiles observées aux instruments méridiens de 1837 à 1881. Tome 4. (18^h à 24^h.) (*Observatory.*) 4to. Paris, 1903

—— : Catalogue de l'Observatoire de Paris. Positions observées des étoiles, 1837–1881. 18^h à 24^h. (*Observatory.*) 4to. Paris, 1902.

—— : Rapport annuel sur l'état de l'Observatoire, 1901, par M. Loewy. (*Observatory.*) 4to. Paris, 1902

Paris, Société Astronomique de France:
Bulletin . . . et revue mensuelle d'astronomie, de météorologie et de physique du globe, 1902–1903. Année 16, no. 7—Année 17, no. 6.
(*Society.*) 8vo. Paris, 1902–1903

Paris, Société Mathématique de France:
Bulletin. Tome 30, fasc. 2—tome 31, fasc. 1.
(*Society.*) 8vo. Paris, 1902–1903

Paris, Société Philomathique:
Bulletin. 9me série. Tome 4, no. 2–4; tome 5, no. 1.
(*Society.*) 8vo. Paris, 1902–1903

Perth, Western Australia, Registrar General:
Statistical Register for the year 1900–1. (Meteorological Observations.)
(*H.M. Govt. in W. Australia.*) fol. Perth, 1901–1903

Philadelphia, American Philosophical Society:
——: Proceedings, Vol. 41, No. 168–171.
(*Society.*) 8vo. Philadelphia, 1902
——: Transactions. New series. Vol. 20, pt. 3.
(*Society.*) 4to. Philadelphia, 1902

Philadelphia, Franklin Institute:
Journal, year 77, 78. Vol. 153, No. 6—Vol. 155, No. 5.
(*Institute.*) 8vo. Philadelphia, 1902–1903

Philadelphia, University of Pennsylvania:
Publications. Vol. 2, pt. 1.
(*Observatory.*) 4to. Philadelphia, 1903
Results of observations with the Zenith telescope of the Flower Astronomical Observatory, 1898–1901. C. L. Doolittle.

Philosophical Magazine:
The London, Edinburgh, and Dublin Philosophical Magazine. Series 6, Vol. 4, 5. (No. 19–30.)
(*Turnor and Horrox Fund.*) 8vo. London, 1902–1903

Pickering (Edward C.):
——: *Variable stars of long period.
(*Author.*) 8vo. Harlem [1901]
——: *A plan for the endowment of astronomical research.
(*Author.*) 8vo. Cambridge, Mass., 1903

Pickering (William H.):
*The canals in the Moon.
(*Author.*) 8vo. New York, 1902

Pingré (Alex. Guillaume):
Annales célestes du dix-septième siècle. Ouvrage publié sous les auspices de l'Académie des Sciences, par G. Bigourdin.
(*Editor.*) 4to. Paris, 1901

Poggendorff's Biographisch-literarisches Handwörterbuch:
Band 4, No. 1–9, herausgegeben von A. J. von Oettingen.
(*Turnor and Horrox Fund.*) 4to. Leipzig, 1902

Pola, Hydrographisches Amt der K. und K. Kriegs-Marine:
Veröffentlichungen, No. 13–15.
(*Hydrographic Office.*) 4to. Pola, 1902

Pola, Sebenico und Teodo:
Meteorologische Termin-Beobachtungen. May 1902—April 1903.
(*Hydrographic Office.*) obl. fol. Wien, 1902–1903

Popular Astronomy. Edited by W. W. Payne and H. C. Wilson. Vol. 10, 11. (No. 96–105.)
(*Editors.*) 8vo. Northfield, Minn., 1902–1903

Potsdam, Astrophysikalisches Observatorium:
Publicationen. Band 12.
(*Observatory.*) 4to. Potsdam, 1902

Potsdam, Centralbureau der Internationalen Erdmessung:
Veröffentlichungen, Neue Folge, No. 6–8.
(*The Bureau.*) 4to. Berlin, 1902–1903

No. 6. A. Marcuse. Ergebnisse der Polhöhenbestimmungen in Berlin.
„ 7. Bericht über die Thätigkeit des Centralbureaus, 1902.
„ 8. Th. Albrecht. Resultate des internationalen Breitendienstes. Bd. 1.

Potsdam, Königl. preussisches Geodätisches Institut:
Veröffentlichung, Neue Folge, No. 8–12.
(*The Institute.*) 4to. and 8vo. Berlin, 1902–1903

No. 8. Jahresbericht des Directors, 1901–1902.
„ 9. Bestimmung der Polhöhe und der Intensität der Schwerkraft.
„ 10. Lotabweichungen. Heft II. A. Börsch und L. Krüger.
„ 11. Bestimmung der Schwerkraft auf dem Atlant. Ozean. O. Hecker.
„ 12. Seismometrische Beobachtungen, 1902. O. Hecker.

Prague, K.K. Sternwarte:
Magnetische und meteorologische Beobachtungen im Jahre 1901. Jahrgang 62 . . . herausgegeben von L. Weinek.
(*Observatory.*) 4to. Prag, 1902

Pulfrich (C.):
——: *Ueber neuere Anwendung der Spectroskopie, und über einen hierfür bestimmten Stereo-Komparator. [2 parts.]
(*Author.*) 4to. Berlin, 1902
——: *Ueber eine Prüfungstafel für stereoskopisches Sehen.
(*Author.*) 4to. Berlin, 1902

Reimann (Eugen):
*Die scheinbare Vergrösserung der Sonne und des Mondes am Horizont.
(*Author.*) 8vo. Leipzig, 1902

Reynolds (Osborne):
The sub-mechanics of the Universe.
(*Royal Society.*) 8vo. Cambridge, 1903

Richmond, Surrey, National Physical Laboratory:
* Report of the . . . Committee of the Royal Society . . . for the year 1901.
(*Laboratory.*) 8vo. London, 1902

Rio de Janeiro, Observatorio:
——: Annuario . . . para o anno de 1902.
(*Observatory.*) 8vo. Rio de Janeiro, 1902
——: Boletim mensal. 1901, 7–12; 1902, 1–9.
(*Observatory.*) 4to. Rio de Janeiro, 1902–1903

Roberts (Sydney A.):
Azimuths of the North pole star, latitude 38° N. to 55° N., for use until the year 1915.
(*Author.*) 4to. Victoria, B.C., 1902

Rome, Reale Accademia dei Lincei:
Atti . . . Anno 299, 300 (1902–1903), Serie quinta. Rendiconti, Classe di scienze fisiche, matematiche e naturali. Vol. 11, semestre 1, fasc. 11, 12, semestre 2, fasc. 1–12: Vol. 12, semestre 1, fasc. 1–9.
(*Academy.*) 4to. Roma, 1902–1903

Rome, Reale Osservatorio del Collegio Romano:
Memorie . . . pubblicate per cura del Direttore P. Tacchini. Serie 3, vol. 3.
(*Observatory.*) 4to. Roma, 1902

Rome, Società Italiana delle Scienze:
Memorie di matematica e di fisica. Serie terza. Tomo 12.
(*Society*). 4to. Roma, 1902

Rome, Specola Vaticana:
Pubblicazioni, Vol. 6.
(*Observatory.*) 4to. Roma, 1902

Rowland (Henry Augustus):
Physical papers . . . collected for publication by a committee of the Faculty of the University.
(*Turnor and Horrox Fund.*) 8vo. Baltimore, 1902

Rugby School Natural History Society:
Report . . . for the year 1902.
(*The School.*) 8vo. Rugby, 1903

San Fernando, Instituto y Observatorio de Marina:
Almanaque Náutico para el año 1904.
(*Observatory.*) 4to. San Fernando, 1902

San Francisco, Astronomical Society of the Pacific:
Publications, Vol. 14, 15 (No. 84–89).
(*Society.*) 8vo. San Francisco, 1902–1903

Schweiger-Lerchenfeld (Armand):
Atlas der Himmelskunde auf Grundlage der Ergebnisse der coelestischen Photographie . . . mit besonderer Unterstützung von L. Weinek.
(*Turnor and Horrox Fund.*) fol. Wien, Pest, Leipzig, 1898

See (T. J. J.):
*Observations of the Satellites of Saturn and Uranus made with the 26-inch refractor of the U.S. Naval Observatory, Washington.
(*Author.*) 4to. Kiel, 1902

Serviss (Garett P.):
Pleasures of the telescope: an illustrated guide for amateur astronomers, and a popular description of the chief wonders of the heavens for general readers.
(*Turnor and Horrox Fund.*) 8vo. London, 1902

Shaw (Frederick G.):
Comets and their tails, and the Gegenschein Light.
(*Author.*) 8vo. London, 1903

Sirius: Zeitschrift für populäre Astronomie; Redakteur H. J. Klein. Band 35, Heft 7–12; Band 36, Heft 1–6.
(*Editor.*) 8vo. Leipzig, 1902–1903

Southport, Fernley Observatory:
Report and results of [meteorological] observations for the year 1902, by J. Baxendell.
(*Author.*) 4to. Southport, 1903

Stockholm, Kongliga Svenska Vetenskaps Akademie:
—— : Bihang till . . . Handlingar. Afdelning 1, Mathematik, Astronomi [&c.]. Bandet 27.
(*Academy.*) 8vo. Stockholm, 1901
—— : Öfversigt af Kongl. Vetenskaps Akademiens Förhandlingar, 1901, 1902. Årgången 58, 59.
(*Academy.*) 8vo. Stockholm, 1901–1903

Stockholm, Observatorium:
Astronomiska Iakttagelser och Undersökningar . . . utgivna af Karl Bohlin. Bandet 6, No. 2, 4: Bandet 7.
(*Observatory.*) 4to. Stockholm, 1898–1903

Stokes (George Gabriel):
Mathematical and physical papers. . . . Reprinted from the original Journals and Transactions, with additional notes by the Author. Vol. 3.
(*Turnor and Horrox Fund.*) 8vo. Cambridge, 1901

Stonyhurst College Observatory:
Results of meteorological and magnetical observations, with report and notes of the director, Rev. W. Sidgreaves. 1902.
(*Observatory.*) 8vo. Clitheroe, 1903

Sydney, Royal Society of New South Wales:
Journal and Proceedings for 1901. Vol. 35.
(*Society.*) 8vo. Sydney, 1902

Sykora (J.):
*Observations sur l'aurore boréale effectuées pendant l'hivernage 1899–1900 de l'expédition Russe à Konstantinovka, Spitzberg. I. Photographie du spectre de l'Aurore.
(*Author.*) 4to. St.-Pétersbourg, 1901

Tacubaya, Observatorio Astronómico Nacional:
——: Anuario . . . para el año de 1903. F. Valle. Año 23.
(*Observatory.*) 8vo. México, 1902
——: Informes presentados á la Secretaria de Fomento por el Director del Observatorio sobre los trabajos del establecimiento . . . 1899–1901.
(*Observatory.*) 8vo. México, 1902

Thibaut (G.):
*Astronomie, Astrologie und Mathematik. (Grundriss der Indo-arischen Philologie.)
(*Turnor and Horrox Fund.*) 8vo. Strassburg, 1899

Thiele (T. N.):
Theory of observations.
(*Author.*) 4to. London, 1903

Toronto, Canadian Institute:
——: Transactions. Vol. 7, pt. 2 (No. 14).
(*Institute.*) 8vo. Toronto, 1902
——: Proceedings, new series, Vol. 2, pt. 5 (No. 11).
(*Institute.*) 8vo. Toronto, 1902

Toulouse, Académie des Sciences, Inscriptions et Belles-lettres:
Mémoires. . . . 10me série. Tome 1, 2.
(*Academy.*) 8vo. Toulouse, 1901–1902

Tromholt (Sophus):
Catalog der in Norwegen bis Juni 1878 beobachteten Nordlichter . . . herausgegeben von J. Fr. Schroeter.
(*Christiania Soc. of Sciences.*) 4to. Kristiania, 1902

Truro, Royal Institution of Cornwall:
Journal, Vol. 15, pt. 1. 1902.
(*Institution.*) 8vo. Truro, 1902

Tschermak's mineralogische und petrographische Mittheilungen: herausgegeben von F. Becke. Neue Folge. Band 21, Heft 4, 5.
(*Editor.*) 8vo. Wien, 1902

Turin, Reale Accademia delle Scienze:
——: Atti, Vol. 37, No. 11–15; Vol. 38, No. 1–7.
(*Academy.*) 8vo. Torino, 1902–1903
——: Memorie, Serie seconda. Tomo 52.
(*Academy.*) 4to. Torino, 1903

United States Coast and Geodetic Survey:
—— : Report of the Superintendent . . . showing the progress of the work during the years 1899-1900 and 1900-1901.
(*Survey Office.*) 4to. Washington, 1901-1902
—— : List and Catalogue of the publications issued by the U.S. Coast and Geodetic Survey, 1816-1902.
(*Survey Office.*) 8vo. Washington, 1902
—— : The Eastern Oblique arc of the United States and osculating spheroid. By Chas. A. Schott. Special publication, No. 7.
(*Survey Office.*) 4to. Washington, 1902

Valentiner (Wilhelm):
Handwörterbuch der Astronomie. Lieferung 27, 28.
(*Turnor and Horrox Fund.*) 8vo. Breslau, 1902

Vautier-Dufour (Aug.):
*La télé-photographie.
(*Author.*) 8vo. Lausanne, 1902

Vienna, Kaiserliche Akademie der Wissenschaften:
—— : Denkschriften . . . Mathematisch-naturwissenschaftliche Classe. Band 69, 70, 73.
(*Academy.*) 4to. Wien, 1901
—— : Sitzungsberichte . . . Mathematisch-naturwissenschaftliche Classe. Abtheilung II.a., Mathematik, Astronomie, Physik, Meteorologie, Mechanik. Band 110, Heft 4-10; Band 111, Heft 1-4.
(*Academy.*) 8vo. Wien, 1901-1902

Vienna, K.K. Gradmessungs-Bureau:
Astronomische Arbeiten . . . ausgeführt unter der Leitung von Th. von Oppolzer. Nach dessen Tode herausgegeben von E. Weiss und R. Schram. Band 12. Längenbestimmungen.
(*Bureau.*) 4to. Wien, 1900

Vienna, K.K. Universitäts-Sternwarte:
Annalen . . . herausgegeben von E. Weiss. Band 14, 17.
(*Observatory.*) 4to. Wien, 1900-1902

Vienna, K. und K. Militär-geographisches Institut:
Astronomische-geodätische Arbeiten. Band 18.
(*Institute.*) 4to. Wien, 1902
Trigonometrische Arbeiten.

Vogel (Hermann Carl):
—— : *Der grosse Refraktor des Königl. Astrophysikalischen Observatoriums zu Potsdam.
(*Author.*) 4to. Berlin, 1902
—— : *ε Aurigæ, ein spectroskopischer Doppelstern.
(*Author.*) 8vo. Berlin, [1902]

Vogel (Hermann Carl)—*continued.*

——: *Der spectroskopische Doppelstern *o* Persei.
(*Author.*) 8vo. Berlin, [1902]

——: *Sind die Linien λ4481 und λ4352 des Magnesium-spektrums geeignet, Aufschlüsse über die Temperatur der Sternatmosphären zu geben?
(*Author.*) 4to. Kiel, 1903

Washburn Observatory of the University of Wisconsin:
Publications. Vol. 11.
(*Observatory.*) 4to. Madison, Wis., 1902
A. S. Flint. Meridian observations for stellar parallax, first series, 1893-96.

Washington, National Academy of Sciences:
Memoirs, Vol. 8. (Sixth Memoir.)
(*Academy.*) 4to. Washington, 1902

Washington, Smithsonian Institution:
——: Annual Report of the Board of Regents, 1900–1901.
(*Institution.*) 8vo. Washington, 1902

——: Smithsonian Miscellaneous Collections. Vol. 41, No. 1259, 1312, 1313, 1314.
(*Institution.*) 8vo. Washington, 1902
No. 1312. Index to the literature of the Spectroscope. A. Tuckerman.

Washington, U.S. Department of Agriculture:
Report of the chief of the Weather Bureau, 1900–1901. Vol. 2.
(*Bureau.*) 4to. Washington, 1902

Washington, United States Naval Observatory:
——: Report of the Superintendent . . . for the year ending June 30, 1902.
(*Observatory.*) 8vo. Washington, 1902

——: Publications. Second Series. Vol. 2.
(*Observatory.*) 4to. Washington, 1902

——: Meteorological Observations and results, 1901–2.
(*Observatory.*) 4to. Washington, 1902

Weinberg (Boris):
Ueber den wahrscheinlichsten Werth der Verbreitungsgeschwindigkeit der Störungen im Aether, nach den bisherigen Bestimmungen. Theil 1. Bestimmung des wahrscheinlichsten Werthes der Lichtgeschwindigkeit nach den astronomischen Beobachtungen [Russian].
(*Author.*) 8vo. Odessa, 1903

Weinek (Ladislaus):
Definitive Resultate aus Prager Polhöhen-Messungen von 1889 bis 1892 und von 1895 bis 1899.
(*Prague Observatory.*) 4to. Prag, 1903

Wislicenus (Walter F.):
Astronomischer Jahresbericht; mit Unterstützung der Astronomischen Gesellschaft herausgegeben von W. F. W. . . . Band 4, enthaltend die Literatur des Jahres 1902.
(*Editor.*) 8vo. Berlin, 1903

Wolf (C.):
Histoire de l'Observatoire de Paris de sa fondation à 1793.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1902

Wolf (Max.):
*Die Nebelflecken am Pol der Milchstrasse. (Königstuhl-Nebelliste No. 3.)
(*Author.*) 4to. Karlsruhe, 1902

Wolfer (A.)
——: *Die Wolf'schen Tafeln der Sonnenfleckenhäufigkeit; Neuausgabe mit Berichtigungen und Ergänzungen.
(*Author.*) 4to. Zürich, 1902
——: *Revision of Wolf's Sun-spot relative numbers.
(*Author.*) 4to. 1902
——: *Über den Inhalt der Nr. 91–93 der Astronom. Mittheilungen [über Sonnenfleckenstatistik].
(*Author.*) 4to. Kiel, 1903

Wright (Thomas):
*Harmonic tidal constants for certain Australian and Chinese ports.
(*Author.*) 8vo. London, 1902

Yale University, Astronomical Observatory:
Transactions, Vol. 1, part 6.
(*Observatory.*) 4to. New Haven, 1902
W. L. Elkin. Parallax of the ten first magnitude stars in the northern hemisphere.

Yerkes Observatory of the University of Chicago:
Bulletin, No. 18, 19.
(*Observatory.*) 8vo. Chicago, 1903

Young (Charles A.):
Manual of Astronomy: a Text Book.
(*Author.*) 8vo. Boston, Mass., 1902

Zeitschrift für Instrumentenkunde: Organ für Mittheilungen aus dem gesammten Gebiete der wissenschaftlichen Technik. Jahrgang 22, Heft 6—Jahrg. 23, Heft 5.
(*Turnor and Horrox Fund.*) 4to. Berlin, 1902–1903

Zürich, Naturforschende Gesellschaft:
Vierteljahrsschrift, Jahrgang 47, Heft 1, 2.
(*Society.*) 8vo. Zürich, 1902

Zürich, Schweizerische meteorologische Centralanstalt:
Annalen, 1900. Jahrgang 37.
(*Institute.*) 4to. Zürich, 1902

Zürich, Sternwarte des Eidg. Polytechnikums:
Publikationen . . . Band 3. Herausgegeben von A. Wolfer. (*Observatory.*) 4to. Zürich, 1902

Zwiers (H. J.):
Recherches sur l'orbite de la comète périodique de Holmes et sur les perturbations de son mouvement elliptique. Deuxième Mémoire.
(*Observatory, Leiden.*) 8vo. Leyde, 1902

PHOTOGRAPHS, &c., PRESENTED TO THE SOCIETY.

Ellis (William)—Diagram showing curves of sun-spots and magnetic elements.

Harvard College Observatory (E. C. Pickering)—Photographic chart of the heavens, taken at the Astronomical Observatory of Harvard College. (53 chart plates.)

Johnson (R. C.)—Photographs of Comet 1902 III. (4 paper prints.)

Lick Observatory—Series of photographs of Solar Eclipses, 1898, 1900, and 1901, taken by the Lick Observatory expeditions. (9 transparencies.)

Lynn (W. T.)—Portrait of John Goodricke (photograph from a painting).

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Nielsen (Victor)—Photographs of Comet Perrine, the Moon, &c. (5 paper prints.)

Payne (W. W.)—Photographs of Leonid Meteor (lantern slide).

Royal Observatory, Greenwich—Photographs of Comet 1902 III, taken at the Royal Observatory. (2 transparencies.)

Wesley (W. H.)—Portraits of Mr. J. R. Hind, Gen. J. F. Tennant, and Dr. A. A. Common. (Enlarged photographs.)

Wolf (Max)—Stereoscopic photographs of Comet 1902 III. (2 paper prints.)

Yerkes Observatory (G. E. Hale and G. W. Ritchey)—A Spectroheliograph of the Sun, and photographs of the Moon and Nebulæ, taken at the Yerkes Observatory.) (12 transparencies and 12 lantern slides.)

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OYAL ASTRONOMICAL SOCIETY.

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JUNE 1903.

ROYAL ASTRONOMICAL SOCIETY.

LIST OF FELLOWS AND ASSOCIATES.

JUNE 1903.

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Should any errors or omissions be found in this List, it is requested that notice thereof be given to the Assistant Secretary.

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1870 Apr. 8		SIR WM. DE W. ABNEY, K.C.B. R.E. D.C.L. F.R.S., VICE-PRESIDENT, PAST PRESIDENT, *Rathmore Lodge, Bolton Gardens South, S.W.*
1902 June 13		Henry Bridger Adames, 17 *Crouch Hall Road, Crouch End, N.*
1883 Mar. 9	*	Rev. E. Aurelius Adams, M.A., 10 *Hove Park Villas, Hove, Sussex.*
1893 Feb. 10		Harold John Adams, M.A., *St. John's, Oakwood Avenue, Beckenham.*
1893 Mar. 10		Maur. Anderson Ainslie, R.N. B.A., *H.M.S. 'Britannia,' Dartmouth.*
1896 Jan. 10	*	Hugh Lancelot Aldis, 10 *Old Grange Road, Durham Road, Sparkhill, Birmingham.*
1885 Mar. 13	*	Wm. Steadman Aldis, M.A., *Old Headington, Oxford.*
1902 Jan. 10		Ashton Charles Allen, *care of Messrs. Stibbard, Gibson & Co., 21 Leadenhall Street, E.C.*
1880 Nov. 12	*	Rev. Francis B. Allison, M.A., *The Vicarage, Peasmarsh, Sussex.*
1867 Nov. 8		Thomas Michael Almond, Port Master, *Brisbane, Queensland, Australia.*

Date of Election.			
1896 Apr. 10		William	Anderson, *Bellevue, Mavis Bank P. O., Jamaica.*
1901 Jan. 11	*	Charles	Anthony, jun., M.Inst.C.E. M.Am.Soc.C.E. *Casilla* 1045, *Buenos Aires, Argentine Republic.*
1899 Feb. 10		Eugene Michael	Antoniadi, 74 *rue Jouffroy, Paris.*
1900 Jan. 12		Raghunath Narayan	Apte, M.A. LL.B., Professor of Mathematics at Rajaram College, *Kolhapur, India.*
1896 Dec. 11		Geo. Alex. Sime	Atkinson, B.Sc., 3 *Oakfield Street, Newport Road, Cardiff, South Wales.*
1899 Feb. 10		John Jepson	Atkinson, *Cosgrove Priory, Stony Stratford, Northamptonshire.*
1903 Feb. 13		Thomas	Ayres, M.Sc., *Twynffald, Blackwood, Monmouth.*
1873 Apr. 9	*	Thos. William	Backhouse, *West Hendon House, Sunderland.*
1888 Feb. 10		Rev. J. Mackenzie	Bacon, *Cold Ash, Newbury, Berks.*
1892 June 10		Rev. James	Baikie, *United Free Church Manse, Ancrum, Roxburghshire, Scotland.*
1900 Nov. 9		Arthur H.	Baker, B.A., 28 *Cautley Avenue, Clapham Common, S.W.*
1875 Mar. 12	*	Sir Robt. Stawell	Ball, M.A. LL.D. F.R.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge, PAST PRESIDENT, *Observatory, Cambridge.*
1898 May 13		George	Banaster, *Bay View, Ramsey, Isle of Man.*
1896 May 8		William	Banks, 70 *Russell Street, Bolton, Lancashire.*
1884 Nov. 14		Pietro	Baracchi, Government Astronomer, *Observatory, Melbourne, Australia.*
1899 Nov. 10		Rev. Thos. Gerrard	Barber, M.A., *Highfield House, Beeford, Hull.*
1895 Feb. 8		Edwin	Bare, *Ruthven Villa, Hainault Road, Leytonstone.*
1893 Feb. 10		Samuel	Barker, *Graywood Tower, Haslemere, Surrey.*
1874 May 8	*	Rev. H. Glanville	Barnacle, M.A., *St. John's College, Grimsarch, Preston, Lancashire.*
1888 Jan. 13	*	Edward Emerson	Barnard, D.Sc. Assoc.R.A.S., *Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.*
1901 Jan. 11		Henry Osmund	Barnard, F.R.Met.Soc., Superintendent of the Trigonometrical Survey, *Surveyor-General's Office, Colombo, Ceylon.*
1879 May 9		Capt. Edward	Barnes, *Ingatestone House*, 60 *Thames Street, Windsor.*
1899 Apr. 14	*	Rev. Ernest William	Barnes, M.A., *Trinity College, Cambridge.*
1881 May 13	*	John Alfred	Barringer, *Friends' School, Rawdon, near Leeds.*
1880 Apr. 9	*	Lt.-Col. T. Preston	Battersby, Army Ordnance Department (late R.A.), *Cromlyn, Rathowen, Westmeath, Ireland;* and *War Office, Pall Mall, S.W.*
1895 Feb. 8		Cte. Aymar de la	Baume Pluvinel, 17 *rue de Constantine, Paris.*

Election.			
May 13		Henry	Baynham, R.N., Captain, *H.M.S. 'Wellesley,' Training Ship, North Shields.*
June 9		Hedley Robert	Beasley, *Private Schools' Association*, 29 *Old Queen Street, Westminster, S.W.*
May 11	*	William Morris	Beaufort, F.R.G.S., 18 *Piccadilly, W.;* and *Athenæum Club, S.W.*
Apr. 14		Ludwig	Becker, Ph.D. F.R.S.E., Professor of Astronomy in the University of Glasgow, *Observatory, Glasgow.*
Jan. 10		John Hind	Bell, 'Nautical Almanac' Office, 3 *Verulam Buildings, Gray's Inn, W.C.*
Feb. 14	*	Frank Arthur	Bellamy, F.R.Met.Soc., *University Observatory;* and 4 *St. John's Road, Oxford.*
Feb. 12		Bertram	Bennett, M.A., *Montpelier, Paignton, South Devon.*
Mar. 9	*	Arthur	Berry, M.A., *King's College, Cambridge.*
Jan. 13		Joseph Ibbitson	Berry, *Hazeldene, Avenue Road, Highgate. N.*
Nov. 9	*	Rev. Frank	Besant, M.A., *Sibsey Vicarage, Boston, Lincolnshire.*
Feb. 10	*	Wm. Henry	Besant, M.A. Sc.D. F.R.S., *St. John's College, Cambridge.*
Jan. 10	*	Walter Ernest	Besley, 75 *The Chase, Clapham Common, S.W.*
Jan. 10		Algernon Sidney	Bicknell, *Barcombe House, Barcombe, Sussex.*
Jan. 8	*	Lieut.-Col. A. C.	Bigg-Wither, *Tilthams, Godalming, Surrey.*
Jan. 14		Raphael Louis	Bischoffsheim, *Observatoire, Nice;* and 3 *rue Taitbout, Paris.*
Apr. 9		Lord	Blythswood, *Blythswood, near Renfrew, Scotland;* and 2 *Seamore Place, Curzon Street, W.*
Apr. 13		Lyndon	Bolton, B.A., *Patent Office, Southampton Buildings, Chancery Lane, W.C.*
Dec. 14		George Cox	Bompas, F G.S. F.R.G.S., 121 *Westbourne Terrace, W.*
Apr. 6		Rev. John	Bone, A K.C., *St. Thomas's Vicarage, Lancaster.*
Jan. 10		James Henry	Booth, F.R.G.S., *Alton, Stoke-upon-Trent, Staffs.*
Nov. 10	*	Robt. Holford M.	Bosanquet, M.A. F.R.S., *Castillo Zamora, Realejo Alto, Teneriffe, Canary Islands.*
Jan. 11	*	Henry Lord	Boulton, *Carácas, Venezuela, South America.*
Jan. 9		Henry	Bourget, D.èsSc. Maître de conférences à l'Université, et Astronome-adjoint à l'Observatoire de Toulouse, 20 *rue St. Jacques, Toulouse, France.*
Feb. 8		Vincent Joseph	Bouton, B.Sc., 9 *Lansdowne Terrace, Hampton Wick.*
Apr. 8		Thomas Frederick	Bowers, B.A., *Darenth, Little Heath, Old Charlton, S.E.*

Date of Election.			
1892 Dec. 9		John A.	Brashear, *Allegheny, Pennsylvania, U.S.A.*
1893 Jan. 13		Martin	Brendel, Ph.D., Professor of Theoretical A omy and Geodesy in the Universit *Schildweg, Göttingen, Germany.*
1877 June 8	*	Thomas Dalby	Brewin, *Burlington House*, 43 *St. Alban's Leicester.*
1894 Jan. 12	*	William	Briggs, M.A. LL.B. F.C.S., *Burlington Cambridge.*
1899 Jan. 13	*	Charles Lewis	Brook, M.A. F.R.Met.Soc., *Harewood Meltham, near Huddersfield, Yorkshir*
1891 Jan. 9	*	Joseph	Brooks, F.R.G.S., *Hope Bank, Nelson Woollahra, Sydney, N.S. Wales, Austr*
1888 Jan. 13		William R.	Brooks, M.A. D.Sc., Director of the Observatory, *Box* 714, *Geneva, N.Y.,*
1889 Jan. 11	*	Ernest William	Brown, M.A. Sc.D. F.R.S., Professor of A Mathematics, *Haverford College, sylvania, U.S.A.; and Christ's C Cambridge.*
1888 Feb. 10	*	John Henry	Brown, 6 *Cambridge Road, Brighton.*
1891 Jan. 9	*	James Stark	Browne, *The Red House, Mount A Ealing, W.*
1890 May 9		Thomas William	Brownell, 64 *Upper Brook Street, Manch*
1865 Mar. 10		John	Browning, 78 *Strand, W.C.*
1887 Dec. 9		Hon. Justice Gainsford	Bruce, K.C., *Yewhurst, Bromley, Ken*
1902 Apr. 11		George Herbert	Bryant, *Drybrook, Gloucestershire.*
1882 Nov. 10	*	Robert	Bryant, B.A. D.Sc., *London Institution, Fi Circus, E.C.*
1892 Dec. 9	*	Walter William	Bryant, B.A., *Royal Observatory, Green* and 179 *Westcombe Hill, Blackheath,*
1894 Jan. 12		John Harrison	Buckley, 70 *Tower Street, Leicester.*
1892 Feb. 12		Charles	Burckhalter, *Chabot Observatory*, and *Linden Street, Oakland, California,*
1874 Nov. 13	*	Sherburne W.	Burnham, Hon. M.A. of Yale C Assoc.R.A.S., Professor of Practica tronomy in the University of Ch 1945 *Orrington Avenue, Evanston, U.S.A.*
1885 Apr. 10	*	Major Sidney G.	Burrard, R.E., Superintendent of the Trigonometrical Survey of India, *Dún, N.W.P., India.*
1865 Apr. 12	*	Col. Alexander	Burton-Brown, R.A. F.G.S., 11 *Union Cr Margate.*
1900 Apr. 11		Thomas C.	Bush, *Somerville, Wells Road, Bath.*
1871 May 12	*	Reginald	Bushell, *Hinderton Lodge, Neston, Cheshir*

Election.			
pr. 10	*	Warren Fredk.	Caborne, C.B. Commander R.N.R. F.R.G.S. F.R.Met.Soc., 54 *Alexandra Road, Upper Norwood, S.E.*
ıne 8	*	George	Calver, *Hill House, Widford, Chelmsford.*
ın. 11		Archd.Young Gipps	Campbell, I.C.S., *Nandiyal Railway Station P.O., Kurnool District, South India.*
pr. 8		Frederick Hugh	Capron, 38 *Arenue Road, Highgate, N.*
ſay 10	*	Edward	Carpmael, B.A. Assoc. Inst. C.E., *The Irises, St. Julian's Farm Road, West Norwood, S.E.*
eb. 14	*	Ernest	Carpmael, M.A. K.C., *Ferndale, Woodside Road, Sutton, Surrey.*
an. 9	*	Major John	Cassells, V.D. J.P., 154 *Queen's Drive, Crosshill, Glasgow.*
ſar. 13	*	James	Cavan, M.A., *Eaton Mascott Hall, Shrewsbury.*
ſay 10	*	Jnan Saran	Chakravarti, M.A., Assistant Accountant-General, *Presidency College Observatory, College Street, Calcutta, India.*
ſov. 14		Rev. James Law	Challis, M.A., *The Vicarage, Stone, Aylesbury.*
'eb. 12		George Fredk.	Chambers, *Lethen Grange, Sydenham, S.E.*
ſar. 8		Robert William	Chapman, M.A. B.C.E., Lecturer in Engineering and Physical Science, *University, Adelaide South Australia.*
an. 9		Lt.-Col. W. St. L.	Chase, V.C. C.B. F.R.G.S., 7th Bombay Infantry, *Quetta, Beluchistan.*
pr. 14		Samuel	Chatwood, M.Inst.M.E. F.R G.S., *High Lawn, Broad Oak Park, Worsley, Manchester.*
ſar. 14		J. W. Lawrence	Child, *Vernham, Merton Hall Road, Wimbledon.*
ſar. 13	*	W. H. Mahoney	Christie, C.B. M.A. D.Sc. F.R.S., Astronomer Royal, PAST PRESIDENT, *Royal Observatory, Greenwich, S.E.*
ec. 11		Lord Edw. Spencer	Churchill, 28 *Grosvenor Street, W.*
eb. 12		John Charles	Clancey, F.R.G.S. F.S.I., Assistant Director of Land Records and Agriculture, *New Public Buildings, Rangoon, Burma.*
une 8		Rev. John Thos. W.	Claridge, M.A., 26 *Edgbaston Road, Moseley, Birmingham.*
an. 12		Maurice Harvey	Clarke, Lieut. R.N.R. F.R.G.S., *Coleswood, Harpenden, Herts;* and *Board of Trade Surveyor's Office, 79 Mark Lane, E.C.*
eb. 14		Thomas Folkes	Claxton, Director of the Royal Alfred Observatory, *Mauritius.*
ſay 14	*	Arthur W.	Clayden, M.A. F.G.S., Principal of the Royal Albert Memorial College, *St. John's, Polsloe Road, Exeter.*

Date of Election.			
1860 Apr. 13	*	Robert Bellamy	Clifton, M.A. F.R.S., Professor of Experimental Philosophy in the University of Oxford, 3 *Bardwell Road, Banbury Road, Oxford.*
1859 Feb. 11		John Francis	Cole, *Westfield, Cheam Road, Sutton, Surrey.*
1900 Nov. 9		William Henry	Colegrave, R.N.R., *Little Tew, Enstone, Oxford.*
1853 June 10		Everard Home	Coleman, 71 *Brecknock Road, Camden Road, N.*
1884 Feb. 8	*	William	Coleman, *The Shrubbery, Buckland, Dover.*
1881 Jan. 14		John	Coles, *Royal Geographical Society,* 1 *Savile Row, W.;* and *Lillooet, Liphook, Hants.*
1875 Nov. 12	*	John Brise	Colgrove, M.A., *Burton House, Loughborough.*
1902 Mar. 14		José	Comas Solá, Director of the Fabra Observatory, *S. Felipe,* 29 *S. Gervasio, Barcelona, Spain.*
1902 May 9		Alexander Eugen	Conrady, F.R.M.S., 89 *St. Alban's Avenue, Bedford Park, W.*
1881 Jan. 14		James	Cook, *University, Sydney, N.S.W., Australia.*
1896 Jan. 10		William Ernest	Cooke, M.A., *Observatory, Perth, West Australia.*
1894 Dec. 14	*	Bryan	Cookson, M.A., *Oakwood, Wylam, R.S.O., Northumberland.*
1883 June 8		Hon. Wm. Heron	Coombs, Commander, R.N., *Port of Spain, Trinidad, West Indies.*
1902 Jan. 10		Arthur Thomas	Cooper, A.M.Inst.E.E., *Rivernook, De Montford Island, Reading, Berks.*
1891 June 12		Rich. Edw. Synge	Cooper, M.Inst.C.E., 59 *Avonmore Road, Kensington, W.*
1881 Jan. 14	*	William Ernest	Cooper, *Henwick Lodge, Worcester.*
1874 Jan. 9	*	Ralph	Copeland, Ph.D. F.R.S.E., Astronomer Royal for Scotland, *Royal Observatory, Blackford Hill, Edinburgh.*
1876 Nov. 12	*	J. Owen	Corrie, B.A. (*No address: see slip*).
1891 Jan. 9	*	Rev. Aloysius L.	Cortie, S.J., *Stonyhurst College Observatory, Blackburn, Lancashire.*
1862 Feb. 14		Arthur	Cottam, *Eldercroft, Essex Road, Watford.*
1896 Feb. 14	*	Philip H.	Cowell, M.A., *Royal Observatory, Greenwich, S.E.*
1890 Mar. 14		Rev. S. Runsie	Craig, B.A. LL.B. F.S.S., *The Rectory, Moville, Londonderry, Ireland.*
1871 Jan. 13	*	The Earl of	Crawford and Balcarres, K.T. LL.D. F.R.S., PAST PRESIDENT, 2 *Cavendish Square, W.*
1868 Feb. 14		George Stickland	Criswick, *Rothley, Mycenæ Road, Westcombe Park, S.E.*
189 Jan. 9	*	William Bladen	Croft, M.A., 9 *College Street, Winchester, Hants.*
1868 Nov. 13	*	Edward	Crofton, 45 *West Cromwell Road, South Kensington, S.W.*
1888 Nov. 9		Andrew C. de la C.	Crommelin, B.A., *Royal Observatory, Greenwich;* and *Benvenue,* 55 *Ulundi Road, Blackheath, S.E.*

Date of Election.			
1901 June 14		Francis William	Crook, B.A., 4 *Overcliff, Gravesend, Kent.*
1867 June 14	*	Edward	Crossley, *Halifax, Yorkshire.*
1890 May 9		George	Cumes, F.R.G.S., *Huntingdon House School, Teddington.*
1879 Jan. 10		Thomas	Cushing, 2 *Southside, Chepstow Road, Croydon.*
1871 June 9	*	Rev. Reginald F.	Dale, M.A., 12 *Bradmore Road, Oxford.*
1888 May 11	*	Thomas R.	Dallmeyer, 25 *Newman Street, Oxford Street, W.*
1898 Dec. 9	*	Lieut. Tristan	Dannreuther, R.N. F.R.G.S., *H.M.S.* '*Leviathan*,' *China Station.*
1892 June 10		John	Dansken, F.S.I., 2 *Hillside Gardens, Partick Hill, Glasgow, Scotland.*
1879 Nov. 14	*	George Howard	Darwin, M.A. LL.D. F.R.S., Plumian Professor of Astronomy in the University of Cambridge, PAST PRESIDENT, *Newnham Grange, Cambridge.*
1888 Jan. 13	*	Major Leonard	Darwin, R.E., 12 *Egerton Place, S.W.*
1901 Jan. 11	*	Charles Rundle	Davidson, *Royal Observatory; and* 41 *Park Street, Greenwich, S.E.*
1889 Mar. 8	*	Rev. C. D. Percy	Davies, M.A., *Fretherne, Stonehouse, Gloucestershire.*
1869 Mar. 12	*	Rev. Robert P.	Davies, M.A., *Hatherop Rectory, Fairford, Gloucestershire.*
1875 May 14	*	Percy L. H.	Davis, '*Nautical Almanac*' *Office*, 3 *Verulam Buildings, Gray's Inn, W.C.*
1889 Nov. 8	*	Richard Evan	Day, M.A., *Culver, Plaistow Lane, Bromley, Kent.*
1877 June 8		William Fredk.	Denning, 34 *Egerton Road, Bishopston, Bristol.*
1895 Feb. 8		Henri	Deslandres, D. ès Sc., *Observatoire, Meudon*, and 56 *bis, Route des Gardes, Bellevue, Seine-et-Oise, France.*
1897 Feb. 12	*	William Fraser	Doak, M.A., '*Nautical Almanac*' *Office*, 3 *Verulam Buildings, Gray's Inn, W.C.*
1893 Nov. 10		William Murray	Dobie, M.D. J.P., *Kirkton House, Chester.*
1898 Nov. 11		Cecil G. J.	Dolmage, M.A. LL.D. D.C.L., 243 *Cromwell Road, South Kensington, S.W.*
1898 Mar. 11		Eric	Doolittle, B.Sc, *Flower Observatory, University of Pennsylvania, Philadelphia, Pa., U.S.A.*
1898 Nov. 11		Andrew Ellicott	Douglass, B.A., Probate Judge, *Flagstaff, Arizona, U.S.A.*
1875 Mar. 12		Arthur M. W.	Downing, M.A. D.Sc. F.R.S., Superintendent of the 'Nautical Almanac,' 3 *Verulam Buildings, Gray's Inn, W.C.*; and 3 *Granville Park, Blackheath*, S.E.

ROYAL ASTRONOMICAL SOCIETY.

LIST OF FELLOWS AND ASSOCIATES.

JUNE 1903.

Date of Election.			
1896 Jan. 10		Alpin G.	Fowler, M.Inst.C.E., 1 *Cambridge Road, Norbiton, Surrey.*
1851 June 13	*	William	Francis, Ph.D. F.L.S. F.C.S., *care of Taylor & Francis, Red Lion Court, Fleet Street, E.C.*
1897 Apr. 9	*	John	Franklin-Adams, *Grange Cottage, Wimbledon*, and *Machrihanish House, Campbeltown, Scotland.*
1880 Jan. 9	*	William Sadler	Franks, *care of Isaac Roberts, F.R.S., Starfield, Crowborough, Sussex.*
1871 Nov. 10		Joseph H.	Freeman, 98 *Romford Road, Stratford, E.*
1896 April 10		Thomas Frederick	Furber, *Trigonometrical Survey of N.S.W., Department of Lands, Sydney, New South Wales, Australia.*
1881 Feb. 11		W. H. St. Quintin	Gage, *High Street, Wolsingham, Darlington.*
1893 May 12		Walter Fred.	Gale, J.P., *Newcastle, New South Wales, Australia.*
1870 Jan. 14	*	William	Garnett, *Low Moor, Clitheroe, Lancashire.*
1870 May 13	*	Charles Henry	Gatty, LL.D. F.R.S.E., *Felbridge Place, East Grinstead, Sussex.*
1872 Dec. 13	*	Edward	Gay, *Invermore, Oxford.*
1894 Nov. 9		S. Maitland Baird	Gemmill, *care of W. L. Wilson*, 50 *Great Western Road, Glasgow.*
1902 May 9	*	Henry Tresawna	Gerrans, M.A., *Worcester College*; and 20 *St. John Street, Oxford.*
1902 May 9		Maurice Edmd. J.	Gheury, 12 *Cressey Road, Hampstead, N.W.*
1894 Mar. 9		A. Sarath Kumar	Ghosh, 28 *Elgin Avenue, Maida Vale, W.*
1900 Jan. 12	*	Umes Chandra	Ghosh, M.A., Lecturer on Mathematics at the Muir Central College, 4 *Mayo Road, Allahabad, N.W.P., India.*
1892 Mar. 11		Arthur	Gibbons, *Science, Art, and Technical School*; and *Wentworth House, South Street, Brierley Hill, Staffordshire.*
1857 Jan. 9	*	William Bolger	Gibbs, *Thornton, Beulah Hill, Upper Norwood, S.E.*
1867 Dec. 13	*	Sir David	Gill, K.C.B. LL.D. F.R.S., His Majesty's Astronomer, *Royal Observatory, Cape of Good Hope.*
1871 Apr. 14	*	J. W. L.	GLAISHER, M.A. Sc.D. F.R.S., VICE-PRESIDENT, PAST PRESIDENT, *Trinity College, Cambridge.*
1874 May 8	*	Joseph	Gledhill, F.R.Met Soc., *Bermerside Observatory, Skircoat, Halifax, Yorkshire.*
1893 Apr. 14	*	Raymond Hill	Godfrey, F.R.G.S., 79 *Cornhill, E.C.*
1885 Jan. 9		Walter	Goodacre, 1 *Birchington Road, Crouch End, N.*
1889 Jan. 11	*	John Jas. Lewis	Goodridge, 38 *St. Denys Road, Portswood, near Southampton.*

lection.			
ıy 8		Thomas	Gordon, F.R.Met. Soc., 9 *Scotch Street, Whitehaven, Cumberland.*
ır. 8		John Ellard	Gore, M.R.I.A., 3 *St. Mary's Road, Pembroke, Dublin.*
ıv. 9		Eugen von	Gothard, *Astrophysikalisches Observatorium, Herény, bei Steinamanger, Hungary.*
ıril 10		Frank L.	Grant, M.A., 58 *Kelvingrove Street, Glasgow, Scotland.*
n. 11		Charles Josephus	Green, M.R.C.S. L.S.A., 10 *St. Paul's Square, Preston, Lancashire.*
ıc. 13		William John	Greenstreet, M.A., *Marling School, Stroud, Gloucestershire.*
ıv. 13	*	John Anderton	Greenwood, B.A. LL.M., *Funtington House, near Chichester, Sussex.*
b. 14		Richard A.	Gregory, *Dell Quay House, near Chichester, Sussex.*
ıb. 8		John E.	Griffith, *Bryn Dinas, Upper Bangor, North Wales.*
ıv. 9	*	Lord	Grimthorpe, M.A. LL.D. K.C., *Batch Wood, St. Albans.*
ıv. 11		Sir Howard	Grubb, F.R.S. M.I.C.E.I., Honorary Master of Engineering, University of Dublin, 51 *Kenilworth Square, Rathgar, Dublin.*
n. 9	*	Rev. H. Grattan	Guinness, D.D. F.R.G.S., *Harley House, Bow, E.;* and *Cliff House, Curbar, viâ Sheffield.*
ıv. 14		Col. Gardiner F.	Guyon, Commanding 7th Regimental District, *Egerton House, Richmond, Surrey.*
ay 9	*	George Thorn	Gwilliam.
ın. 10		David Edward	Hadden, *Alta, Buena Vista Co., Iowa, U.S.A.*
ay 8	*	George E.	Hale, D.Sc. Assoc.R.A.S., Director of the Yerkes Observatory, *Williams Bay, Wisconsin, U.S.A.*
ar. 8	*	Rev. Frederic J.	Hall, M.A., *Northaw Place, Potter's Bar, Hertford.*
eb. 10		John James	Hall, *Observatory Cottage, Datchet Road, Slough, Bucks.*
ay 10		Maxwell	Hall, M.A., *Montego Bay, Jamaica;* and *care of Miss Hall, 10 Osborne Road, Clifton, Bristol.*
eb. 13		G. P. Blackwood	Hallowes, 48 *Queen Anne's Road, York.*
ın. 11		Frederic	Hammond, F.R.I.B.A., 38 *Mercers Road, Tufnell Park, N.*
ın. 13		Arthur	Hands, M.R.C.S., L.R.C.P., *Inkerman House, Wednesfield Road, Wolverhampton.*
ın. 13	*	Rev. Thomas	Hands, M.A., *St. Laurence's Vicarage, Northampton.*

Date of Election.			
1902 Jan. 10	*	Joseph Alfred	Hardcastle, 38 *Eaton Square, S.W.*
1903 Jan. 9		Patrick Sinclair	Hardie, M.A. B.Sc., 4 *Greenmount Gardens, Burntisland, Scotland.*
1877 Feb. 9		George Francis	Hardy (*No address: see slip*).
1854 Jan. 13	*	Rev. Robert	Harley, M.A. F.R.S., *Rosslyn, Westbourne Road, Forest Hill, S.E.*
1883 Apr. 13		Rev. Timothy	Harley, *The Torrs, Wallington, Surrey.*
1890 Feb. 14		Alfred Newton	Harris, 5 *Clarendon Place, The Hoe, Plymouth.*
1882 Jan. 13		Jasper Nicolls	Harrison, *Saling Grove, Braintree, Essex.*
1899 Jan. 13		Samuel Henry	Harrison, F.R.G.S., *Frederick Road, Edgbaston, Birmingham.*
1902 Mar. 14		Rev. J. Horsley	Haslam, M.A., *St. Saviour's Vicarage, Denmark Park, S.E.*
1900 Jan. 12		Richd. Kilvington	Hattersley, F.R.G.S., 4 *Church Terrace, Blackheath, S.E.*; and *Rand Club, Johannesburg, S. Africa.*
1901 Jan. 11		Walter	Heath, M.A., *Uplands, Cobham, Surrey.*
1878 Feb. 8		Henry Burdett	Hederstedt, C.E. F.R.G.S., *Lucknow, India*; and *Twyford Lodge, Southlands Road, Bickley, Kent.*
1885 Jan. 9		Rev. Andrew	Henderson, LL.D., *Castlehead, Paisley, Scotland.*
1890 May 9	*	Lt.-Col. George	Henderson, M.R.A.S. F.S.A.Scot. F.R.S.North Antiq., 7 *Mincing Lane, E.C.*
1890 Feb. 14		Fredk. William	Henkel, B.A., 7 *Barrowby High Road, Grantham.*
1864 Feb. 12		John B. N.	Hennessey, C.I.E. M.A. F.R.S. F.R.G.S., 18 *Alleyn Park, West Dulwich, S.E.*; and *Athenæum Club, S.W.*
1887 Apr. 6		Capt. M. W. C.	Hepworth, C.B. R.N.R., Marine Superintendent, Meteorological Office, 63 *Victoria Street, S.W.*; and 2 *Amherst Road, Ealing, W.*
1897 Mar. 12		J. Harold	Herbert, *Hazlemont, The Boulevard, Nottingham.*
1867 Mar. 8	*	Prof. Alex. Stewart	Herschel, M.A. D.C.L. F.R.S., *Observatory House, Slough, Bucks.*
1872 Feb. 9	*	Col. John	Herschel, R.E. F.R.S., Member of Senate, Calcutta University; *Observatory House, Slough, Bucks.*
1901 Jan. 11	*	John Chas. Wm.	Herschel, B.A. Oxon., *St. John's College, Cambridge*; and *Lawn Upton, Littlemore, near Oxford.*
1893 Dec. 8	*	Major Edm. H.	Hills, C.M.G. R.E., 32 *Prince's Gardens, S.W.*
1899 Jan. 13	*	Arthur Robert	Hinks, M.A., *Observatory, Cambridge.*
1891 Feb. 13	*	Shin	Hirayama, *The Observatory, Azabu, Tokyo, Japan.*
1895 Mar. 8		George Denton	Hirst, 379 *George Street, Sydney, New South Wales, Australia.*
1895 June 14		Ernest William	Hobson, Sc.D. F.R.S., *Christ's College, Cambridge.*

Date of Election.			
1895 Mar. 8		Samuel V.	Hoffman, 91 *Madison Avenue, Morristown, New Jersey, U.S.A.*
1890 Nov. 14		Neville	Holden, *Queen Square, Lancaster.*
1884 Dec. 12		Henry Park	Hollis, B.A., *Royal Observatory, Greenwich*; and 2 *Foyle Road, Blackheath, S.E.*
1868 June 12		Henry William	Hollis, *Norbiton Hall, Kingston-on-Thames.*
1885 Apr. 10		Rev. Canon J. H.	Honeyburne, M.A. 23 *Duke Street, Southport.*
1879 Mar. 14	*	Maures	Horner, *Mells, Frome, Somerset.*
1884 Apr. 9		Charles	Horsley, M.Inst.C.E. F.G.S., 174 *Highbury New Park, N.*
1873 Dec. 12	*	Joseph	Hough, M.A., *Codsall Wood, near Wolverhampton.*
1899 Nov. 10	*	Sydney Samuel	Hough, M.A. F.R.S., *Royal Observatory, Cape of Good Hope.*
1881 Jan. 14		Elijah	Howarth, *Public Museum, Weston Park, Sheffield.*
1902 Jan. 10		Charles Sumner	Howe, Ph.D., Professor of Astronomy, *Case Observatory, Cleveland, Ohio, U.S.A.*
1861 Mar. 8		Rev. Frederick	Howlett, M.A., 7 *Princes Buildings, Clifton, Bristol.*
1898 Feb. 11	*	Thomas Charlton	Hudson, B.A., '*Nautical Almanac*' *Office, Gray's Inn, W.C.*; and 37 *Lambton Road, Hornsey Rise, N.*
1854 Apr. 12	*	Sir WILLIAM	HUGGINS, K.C.B. O.M. D.C.L. LL.D. Ph.D. D.Sc. P.R.S., FOREIGN SECRETARY, PAST PRESIDENT, 90 *Upper Tulse Hill, S.W.*
1898 Feb. 11		David	Hunter, *St. Ronan's, Lanark, Scotland.*
1885 Dec. 11		James	Hunter, F.R.C.S.E. F.R.P.S. F.R.S.E., *Rosetta, Liberton, Midlothian, Scotland.*
1886 Dec. 10		Rev. Robt. Sparke	Hutchings, *The Vicarage, Alderbury, Salisbury.*
1887 Jan. 14		Cuthbert	Hutchinson, *Rock Lodge, Roker, near Sunderland.*
1902 Jan. 10		William Gylby	Hutchinson, *Rock Lodge, Roker, near Sunderland.*
1879 Jan. 10		Robert T. A.	Innes, Director of the Transvaal Meteorological Department, *P.O. Box* 858, *Johannesburg, South Africa.*
1861 Feb. 8	*	Richard	Inwards, 20 *Bartholomew Villas, Kentish Town N.W.*
1901 Mar. 8		Charles John	Isaac, Head of the Upper Nautical School, *Royal Hospital School*; and 6 *Maze Hill, Greenwich, S.E.*
1888 Jan. 13	*	George James	Jacobs, *The Homestead, White Rose Lane, Woking.*
1890 Nov. 14		Harold	Jacoby, B.A. Ph.D., Adjunct Professor of Astronomy, *Astronomical Observatory, Columbia University, New York City, U.S.A.*

Date of Election.			
1892 May 13	*	Sir Otto	Jaffe, 10 *Donegall Square South, Belfast, Ire*
1898 Mar. 11		Rev. Kingsbury	Jameson, M.A., *Highfield, Hendon.*
1891 Jan. 9		Charles W. H.	Jeavons, *Horseley Place, Tipton, Staffordsh*
1878 Nov. 8		Benjamin George	Jenkins, 43 *Chatsworth Road, West Dul S.E.*
1892 May 13		Charles Henry	Johns, M.A., 20 *Goring Road, Llanelly, W*
1902 Jan. 10		Geo. Frederick	Johns, *Observatory, Perth, West Australia*
1888 May 11		Rev. Alfred Robt.	Johnson, M.A., *The Rectory, Marwood, Barnstaple.*
1876 Jan. 14		Richard Coward	Johnson, 54 *Fern Grove, Sefton Park, Live*
1872 Mar. 8	*	Rev. Samuel J.	Johnson, M.A., *The Vicarage, Melplash, B Bridport, Dorset.*
1885 Dec. 11	*	Walter Claude	Johnson, M.Inst.C.E., *The Dignaries, combe Park, Blackheath, S.E.*
1897 Jan. 8		William	Johnston, 130 *Wotton Hill, London Gloucester.*
1898 Apr. 6	*	Charles Jasper	Joly, M.A. F.T.C.D., Andrews Professor o tronomy in the University of Dublin Royal Astronomer of Ireland, *Observ Dunsink, Co. Dublin, Ireland.*
1895 Dec. 13	*	Rhishard Llewelyn	Jones, M.A., Professor of Physics, Presi College, Madras, *Nungumbaukum, M India.*
1867 May 10	*	John	Joynson, *Thornton Lodge, Thornton, Crosby, Liverpool.*
1900 Dec. 14		Sree Rajah A. V.	Jugga Rao Bahadur Garu, F.R.Met.Soc. F. F.S.A. Asst.-Int.d.Bot. Zamindar of mahamed-puram and Yambram Es *Daba Gardens, Waltair Ry. Station, M Presidency, India.*
1894 Jan. 12		Joshua	Jukes, *Sea View Terrace, Aberdovey, North*
1901 Jan. 11		Jas. Netherclift	Jutsum, Cardiff Nautical Academy, 47 *hamon Embankment, Cardiff, South W*
1903 Feb. 13		Charles William	Keighley, *Cluny Villa, Burlington Chiswick, W.*
1894 Apr. 13		Wm. Redfern	Kelly, M.Inst.C.E., *Dalriada, Malone Park fast, Ireland.*
1868 Nov. 13	*	Lord	Kelvin, O.M. M.A. LL.D. D.C.L. F Professor of Natural Philosophy in University of Glasgow, *Glasgow, Scotl*
1893 May 12		Rev. Philip H.	Kempthorne, M.A., *Wellington College, Be*
1893 June 9	*	Arthur E.	Kennelly, Professor of Engineering, *Ha* College' *Cambridge, Mass., U.S.A.*

Election.			
Jan. 8	*	David Joseph	Kennelly, *Sydney, C.B., Nova Scotia, Canada.*
Jan. 9		Richard	Kerr, F.G.S., *Fairview, 2 Sibthorpe Terrace, near Tooting Junction, Mitcham, S.W.*
Feb. 14		William Ambrose	Kibbler, M.B., *Ashby House, 3 Manor Road, Stamford Hill, N.*
Jan. 10		Rev. Robert	Killip, 81 *Newsham Drive, Liverpool.*
Apr. 8		Alphonso	King, 93 *Victoria Road East, Leicester.*
Jan. 14	*	Sydney T.	Klein, F.L.S. F.E.S., *Hatherlow, Raglan Road, Reigate, Surrey.*
Jan. 10		George Handley	Knibbs, *The University, Sydney;* and *Spottiswoode, Bland Street, Ashfield, near Sydney, New South Wales, Australia.*
Dec. 12		Geo. McKenzie	Knight, 25 *Holford Square, Percy Circus, W.C.*
Jan. 11		Lt.-Col. H.S.G.S.	Knight, *The Observatory, Harestock, Littleton, near Winchester;* and *Army and Navy Club, Pall Mall, S.W.*
Mar. 13		Thomas Edward	Knightley, *Clive House, Tulse Hill, S.W.*
Mar. 14		Edward Ball	Knobel, PAST PRESIDENT, 32 *Tavistock Square, W.C.*
Jan. 10		Vernon Edwin	Knocker, *Lingwood, Grange Road, Deal.*
Mar. 8	*	Lieut. Henry T.C.	Knox, F.R.G.S., late R.N., 14 *King Street, Portman Square, W.*
Apr. 8	*	Carlton John	Lambert, M.A., *Royal Naval College, Greenwich, S.E.*
May 8		William James	Lancaster, F.C.S. F.G.S. F.R.M.S., *Colmore Row, Birmingham;* and *Pine Crest, Barnt Green, Worcestershire.*
Feb. 10	*	Joseph	Larmor, M.A. D.Sc. F.R.S., Lucasian Professor of Mathematics, *St. John's College, Cambridge.*
Nov. 9	*	Arthur Herbert	Leahy, M.A., *Firth College, Sheffield.*
May 11		Désiré Ernest	Lebon, Agrégé de l'Université, Lauréat de l'Academie Française, Professeur de Mathématiques au Lycée Charlemagne, 4 *bis, rue des Écoles, Paris, Ve.*
Feb. 11	*	Rev. Edmund	Ledger, M.A., *Protea, Reigate, Surrey.*
Feb. 12	*	John	Lee (*No address: see slip*).
Jan. 8		Edward Herbert	Lees, *Fairhaven, Mallacoota, East Gippsland, Victoria, Australia.*
Jan. 12		Henry Alfred	Lenehan, *Government Observatory, Sydney, New South Wales, Australia.*

Date of Election.		
1902 Apr. 11	* Capt. G. Ponsonby	Lenox-Conyngham, R.E. *Mussoorie, N.W.P., India.*
1894 Jan. 12	Armin Otto	Leuschner, B.A. Assistant Professor of Astronomy in the University of California, *Berkeley, California, U.S.A.*
1871 Mar. 10	* Fredk. Wm.	Levander, 30 *North Villas, Camden Square, N.W.*
1897 Feb. 12	Rev. Edw. Spry	Leverton, M.A., *The School House, Kirkham, Lancashire.*
1884 Dec. 12	Thomas	Lewis, *Royal Observatory, Greenwich;* and *Herbert Villa, Ulundi Road, Blackheath, S.E.*
1873 Feb. 14	* William J.	Lewis, Professor of Mineralogy in the University of Cambridge, *Mineralogical Museum, Cambridge.*
1873 Feb. 14	* Adolph F.	Lindemann, *Sidholme, Sidmouth, Devon.*
1899 Apr. 14	Capt. Windeyer G.	Lingham, *care of W. Lund, 3 East India Avenue, E.C.*
1877 Jan. 12	* Louis Stromeyer	Little, B.A. M.D., 31 *Grosvenor Street, W.;* and *Reform Club, Pall Mall, S.W.*
1897 Dec. 10	* Wm. Jas. Stewart	Lockyer, M.A. Ph.D., 16 *Penywern Road, Earl's Court, S.W.*
1874 Nov. 14	* Sir Edmund Giles	Loder, Bart., M.A., *Leonardslee, Horsham, Sussex.*
1886 Jan. 8	* Jacob Gerhard	Lohse, *Fünfhausen, bei Elsfleth, Germany.*
1897 June 11	* Henry C.	Lord, Director of the Emerson McMillin Observatory and Assistant Professor of Astronomy, *Ohio State University, Columbus, Ohio, U.S.A.*
1897 Feb. 12	Ernest F. J.	Love, M.A. Assistant Lecturer and Demonstrator in Natural Philosophy in the University, 213 *Royal Parade, Melbourne, Victoria, Australia.*
1876 June 9	* James	Love, 33 *Clanricarde Gardens, Bayswater, W.*
1902 Jan. 10	James William	Lowber, M.A., Sc.D., Ph.D., LL.D., F.R.G.S., F.R.Met.Soc., 113 *East 18th Street, Austin, Texas, U.S.A.*
1889 Feb. 8	* Arthur C. W.	Lowe, B.A., *Gosfield Hall, Halstead, Essex.*
1901 June 14	* Frank	Lowman, B.A., Lecturer in Science, *St. John's College, Battersea, S.W.*
1897 Jan. 8	George Edward	Lumsden, Assistant Secretary of the Province of Ontario, 57 *Elm Avenue, Toronto, Canada.*
1902 Mar. 14	Joseph	Lunt, B.Sc., F.I.C., *Royal Observatory, Cape of Good Hope.*
1862 Feb. 14	* William Thynne	Lynn, B.A., 26 *South Vale, Blackheath, S.E.*
1880 June 11	Major F. Denis F.	MacCarthy, R.E., *South Road, Curragh Camp, Co. Kildare, Ireland.*

Date of Election.			
1896 Jan. 10		Fredk. William	McCarthy, 11 *Colet Gardens, West Kensington, W.*
1882 Nov. 10		Jonadab	McCarthy, 11 *Colet Gardens, West Kensington, W.*
1902 Nov. 14		Francis Kennedy	McClean, *Rusthall House, Tunbridge Wells.*
1877 Mar. 9		Frank	McClean, M.A. LL.D. F.R.S., *Rusthall House, Tunbridge Wells*; and 1 *Onslow Gardens, South Kensington, S.W.*
1886 May 14		John David	McClure, M.A. LL.D., *Mill Hill School, N.W.*
1894 Jan. 12		Henry	MacEwen, 5 *Wendover Crescent, Mount Florida, Glasgow, Scotland.*
1892 May 13		William Grant	MacGregor, F.R.G.S., 18 *Coleman Street, E.C.*
1885 Apr. 10	*	James	McKerrow, 86 *Ghuznee Street, Wellington, New Zealand.*
1884 Dec. 12	*	The Hon. Lord	McLaren, LL.D., 46 *Moray Place, Edinburgh.*
1897 Jan. 8		MajorPercyAlexr.	MacMahon, D.Sc., F.R.S., *Artillery College, Woolwich*; and *Queen Anne's Mansions, Westminster, S.W.*
1879 Mar. 14		Col. Ernest E.	Markwick, *Army Ordnance Department, Thorneycroft, Bourne Avenue, Salisbury.*
1875 Jan. 8		Charles H.	Marten, *Conduit Lodge, Blackheath Park, S.E.*
1901 Jan. 11		Capt. Joseph W.	Martyr, *care of Gen. Martyr*, 8 *Mowbray Road, Upper Norwood, S.E.*
1898 Jan. 14		J. Nevil	Maskelyne, 88 *Trinity Road, Upper Tooting, S.W.*
1893 Mar. 10		Henry Bateman	Massey, *Spalding, Lincolnshire.*
1898 June 10	*	Peter	Matthews, *care of Zaoh. Cartwright, Ltd., Muscovy House, Trinity Square, Tower Hill, E.C.*
1875 Feb. 12	*	Edward Walter	Maunder, *Royal Observatory, Greenwich, S.E.*; and 86 *Tyrwhitt Road, St. John's, S.E.*
1888 Dec. 14		WILLIAM HENRY	MAW, TREASURER, 18 *Addison Road, Kensington, W.*
1895 May 10	*	John Willoughby	Meares, Electrical Engineer to Government of Bengal, 58 *Chowringhee, Calcutta, India.*
1877 Mar. 9	*	Raphael	Meldola, F.R.S. F.C.S. F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute, 6 *Brunswick Square, W.C.*
1859 Mar. 11	*	John James	Mellor, *The Woodlands, Whitefield, near Manchester.*
1883 June 8	*	Thomas Kilner	Mellor, *Vernon Avenue, Huddersfield.*
1901 May 10		Charles Sidney	Mence, *Nautical Academy*, 49 *Watling Street, E.C.*
1896 Jan. 10		Charles J.	Merfield, *Railway Construction, Public Works, Sydney, New South Wales, Australia.*
1886 Feb. 12		Duncan	Milligan, 21 *Spencer Rd., New Wandsworth, S.W.*

Date of Election.			
1900 Nov. 9		Cte. Meredyth de	Miremont, *Orleans Club, King Street, James's Street, S.W.*; and *The Old H Millbrook, Southampton.*
1891 Jan. 9	*	Rev. John	Mitchell, Jun., M.A., *Bankura, Bengal, In*
1890 Dec. 12	*	Rev. John Cairns	Mitchell, B.D., *Rutland Cottage, Parkgate R Chester.*
1902 Apr. 11		S. Alfred	Mitchell, A.M. Ph.D., Lecturer in Astron *Columbia University, New York City, U*
1881 Mar. 11		James Henry	Mitchiner, *The Acacias, 12 Moreton Road, Croydon.*
1892 Feb. 12		Arthur Hilton W.	Molesworth, B.A., 15 *Park Lane, W.*
1898 June 10	*	Capt. Percy B.	Molesworth, R.E., *Trincomali, Ceylon.*
1886 Apr. 9		Wm. Hy. Stanley	Monck, M.A., 16 *Earlsfort Terrace, Dublin*
1901 Jan. 11		Alfred Ernest	Moore, B.A. B.Sc. (Lond.), *St. John's C Battersea, S.W.*
1879 Jan. 10		Rev. J. Holdsworth	Morgan, *Hillside, Woburn Sands, R.S.O., B*
1900 June 8		Forest Ray	Moulton, Ph.D., Instructor in Astronomy Celestial Mechanics at the Unive *Chicago, U.S.A.*
1874 Dec. 11		John Fletcher	Moulton, M.A. K.C. F.R.S., 57 *Onslow S South Kensington, S.W.*
1885 Jan. 9	*	Asutosh	Mukhopadhyay, M.A. LL.D. F.R.S.E., Pro of Mathematics at the Indian Associati the Cultivation of Science, 77 *Russa North, Bhowanipur, Calcutta, India.*
1863 Jan. 9	*	Richard	Munday, *Edgecombe, Thorn Park, Plymou*
1885 Jan. 9		Kavasjee D.	Naegamvala, M.A., *The Maharajah Takhta Observatory, Poona, India.*
1889 Jan. 11	*	Frederick Wm.	Nash, *The Firs, Bentley Heath, K Warwickshire.*
1875 Dec. 10		Commr. Chas. B.	Neate, R.N., *Sibertswold, Dover.*
1888 May 11		Reginald Carter	Nelson, 19 *Roker Terrace, Sunderland.*
1873 Feb. 14		Edmund Neville	Nevill, Government Astronomer, *Observ Durban, Natal.*
1891 June 12	*	HUGH FRANK	NEWALL, M.A. F.R.S. VICE-PRESIDENT, *ingley Rise, Cambridge.*
1888 Apr. 13	*	George James	Newbegin, *Thorpe St. Andrew, Norwich.*
1875 Dec. 10	*	Francis Murray	Newton, *Leigh Court, Craddock, Cullon Devon.*
1877 Apr. 13	*	Frederic	Newton, 3 *Fleet Street, E.C.*
1887 May 13	*	Gustavus William	Nicolls, 9 *Park Road, Forest Hill, S.E.*
1902 Jan. 10		H. Krauss	Nield, 69 *Ravensbourne Road, Bromley, K*
1901 June 14	*	Charles	Nielsen, 15 *Cliff Terrace, Hartlepool.*

Date of Election.			
1901 Jan. 11		Thos. Marginson	Nightingale, B.Sc. (Vict.), 375 *Bridgman Street, Bolton, Lancashire.*
1854 June 9		Sir Andrew	Noble, K.C.B. F.R.S. F.C.S., *Jesmond Dene House, Newcastle-on-Tyne.*
1890 Jan. 10	*	Benjamin	Noble, F.S.S., *Westmoreland House, Low Fell, Gateshead.*
1855 June 8	*	Capt. William	Noble, *Forest Lodge, Maresfield, Uckfield, Sussex.*
1897 May 14		Herbert L. N.	Noel-Cox, 212 *Portland Road, Newcastle-on-Tyne.*
1889 Nov. 8		James	Oddie, J.P. F.G.S. F.R.G.S., *Observatory, Ballaarat, Victoria. Australia.*
1881 May 12		Samuel	Okell, *Overley, Langham Road, Bowdon, near Manchester.*
1903 May 8		Ole Theodor	Olsen, 116 *St. Andrew's Terrace, Grimsby.*
1853 Jan. 14	*	Adm. Sir Erasmus	Ommanney, K.C.B. LL.D. F.R.S. F.R.G.S., 29 *Connaught Square, Hyde Park, W.;* and *United Service Club, Pall Mall.*
1902 Jan. 10		Capt. Michael J.	O'Sullivan, Board of Trade Surveyor, 58 *Bryn Road, Swansea, South Wales.*
1903 May 1		Capt. Ernest W.	Owens, *Local Marine Board, Dock Street, E.;* and 16 *Therapia Road, Honor Oak, S.E.*
1886 Jan. 8	*	William Irving	Page, F.R.G.S., *The White Cottage, Shanklin, Isle of Wight.*
1895 June 14	*	Rev. Jas. Dunne	Parker, LL.D. D.C.L. F.R.Met.Soc., *Bennington House, Stevenage, Herts.*
1903 May 8		Rafel	Patxot Jubert, *Passeig Bonanova* 64, *Barcelona, Spain.*
1900 Jan. 12		Howard	Payn, F.R.G.S., 8 *Hyde Park Place, W.*
1899 June 9		Frederick Evan	Peach, B.A., 161 *Stanstead Road, Forest Hill, S.E.*
1877 Jan. 12	*	Robert	Pearce (*No address: see slip*).
1885 Mar. 13		William	Peck, F.R.S.E., 6 *Hanover Street;* and *City Observatory, Calton Hill, Edinburgh.*
1879 Jan. 10		Charles	Pendlebury, M.A., *St. Paul's School, Kensington, W.;* and 40 *Glazbury Road, West Kensington, W.*
1885 June 12		Rev. Thomas	Perkins, M.A., *Turnworth Rectory, Blandford, Dorset.*
1895 Feb. 8	*	Chas. Wm. Dyson	Perrins, *Davenham Bank, Malvern.*
1889 May 10		James George	Petrie, 359 *Holloway Road, N.*
1870 Jan. 14	*	J. E. Hunter	Peyton, 13 *Fourth Avenue, Brighton.*
1902 Nov. 14		Rev. Edwin A.	Phillips, B.A., *The Training College, Exeter.*
1899 May 12		Rev. Theodore E.R.	Phillips, M.A., *Ryde House, Campbell Road, Croydon.*
1891 Jan. 9		William M.	Pierson, 2214 *Van Ness Avenue, San Francisco, California, U.S.A.*

Date of Election.			
1872 June 12	*	Major Chas. Fred.	Plant, *Ferndale, Ashgrove, Brisbane, Qu land, Australia.*
1899 Dec. 8	*	Henry C.	Plummer, M.A., *University Observatory;* 8 *Holywell Street, Oxford.*
1879 May 9		William Edward	Plummer, M.A., *Liverpool Observatory, Bid Birkenhead.*
1893 Nov. 10		Charles Lane	Poor, Ph.D., *Johns Hopkins University;* 4 *East 48th Street, New York City, U.S.*
1885 Jan. 9	*	Rev. T. Cunningh[m]	Porter, B.A., *Eton College, Windsor.*
1895 Feb. 8		Charles A.	Post, 16 & 18 *Exchange Place, New York* and *Strandhome, Bayport, Suffolk Co N.Y., U.S.A.*
1894 Mar. 9		Walter A.	Post, *Newport News, Warwick County, Virg U.S.A.*
1854 Jan. 13	*	Eyre Burton	Powell, C.S.I. M.A., 25 *Kirkstall Road, Strea Hill, S.W.*
1903 June 12		Alfred	Pratt, B.A. B.Sc., 14 *Endwell Road, Bro S.E.*
1901 Apr. 12		Rev R. Coad	Pryor, *Bengeo Rectory, Hertford.*
1896 Jan. 10		Hugh Griffith	Quirk, *Bay Mount, Vico Road, Dalkey, Dublin, Ireland.*
1893 June 9	*	Arthur A.	Rambaut, M.A. D.Sc. F.R.S., Radcliffe Obs *Radcliffe Observatory, Oxford.*
1879 Jan. 10		Capt. James	Rankin, *Local Marine Board, Dock Street,*
1902 Apr. 11		James	Rankine, 11 *West Savile Road, Craig Park, Edinburgh.*
1883 Nov. 9		Robert	Rawson, Assoc. Inst.N.A., *Warblington Havant, Hants.*
1902 Mar. 14		Joges Chandra	Ray, M.A., Professor of Physical Sc *Cuttack, Orissa, India.*
1866 Jan. 12	*	Lord	Rayleigh, O.M. M.A. Sc.D. LL.D. F.R.S., *Terling Place, Witham, Essex.*
1893 Dec. 8		Chas. Herbt. Edm.	Rea, A.I.A. F.S.S., 223 *Norwood Road, Hill, S.E.*
1888 Apr. 13	*	Capt. Geo. Wm.	Read, F.R.G.S., *Penwerris, Cathedral Cardiff, South Wales.*
1892 Apr. 8		John Krom	Rees, A.M. E.M. Ph.D. Director of the Ob tory, and Professor of Astronomy, *Col University, New York City, U.S.A.*
1896 April 10		Edward Ayearst	Reeves, *Royal Geographical Society*, 1 *Savil W.*
1896 Feb. 14	*	Robert Fermor	Rendell, B.A., *Natal Observatory, D Natal.*

of Election.			
Feb. 10		John H.	Reynolds, 35 *Trinity Road, Birchfield, Birmingham.*
June 10		William John	Reynolds, *Varna, Fox Lane, Palmer's Green, N.*
Jan. 12		Rev. David Powell	Richards, M.A., R.N., *H.M.S. 'Flora,' S.E. Coast of America.*
Feb. 11	*	Rev. Walter J. B.	Richards, D.D., *St. Charles' College, Ladbroke Grove Road, Notting Hill, W.*
Jan. 9	*	Arthur	Riches, *Warwick School, Warwick.*
Apr. 8		Edward Henry	Riches, LL.D., 29 *St. Thomas' Street, Weymouth.*
May 11		Emanuel	Ristori, Assoc. M.Inst.C.E., *Edinburgh Lodge, Howick Place, Victoria Street, Westminster, S.W.;* and *Cippenham House, Slough, Bucks.*
Apr. 6		William	Ritchie, *City Observatory, Calton Hill, Edinburgh.*
May 9	*	Frank	Robbins, 93 *Aldersgate Street, E.C.;* and 99 *Hurlingham Road, S.W.*
Mar. 9		Alex. William	Roberts, D.Sc. F.R.S.E., *Lovedale, Cape Colony.*
Feb. 9		Edward	Roberts, F.S.S., *Park Lodge, Eltham, Kent.*
Jan. 13	*	Isaac	Roberts, D.Sc. F.R.S., *Starfield, Crowborough, Sussex.*
Apr. 11		Edward	Robinson, 133 *Castelnau Gardens, Barnes, S.W.*
Feb. 9		William Henry	Robinson, *Offendene, Walsall, Staffordshire.*
Dec. 12		Rev. W. Jas. Boden	Roome, *Egerton, Acton, W.*
Jan. 11		Rev. Thomas	Roseby, M.A. LL.D., *The Manse, Marrickville, New South Wales, Australia.*
Dec. 13	*	The Earl of	Rosse, K.P. B.A. LL.D. D.C.L. F.R.S., *Birr Castle, Parsonstown, Ireland;* and *Athenæum Club, Pall Mall, S.W.*
Apr. 13	*	Edward John	Routh, M.A. Sc.D. LL.D. F.R.S., Fellow of the University of London, *Newnham Cottage, Queen's Road, Cambridge.*
Feb. 10		Hy. Chamberlaine	Russell, C.M.G. B.A. F.R.S., Government Astronomer, *Observatory, Sydney, N.S. Wales.*
Feb. 13		Henry Norris	Russell, Ph.D., *Oyster Bay, New York, U.S.A.;* and 69*a Trumpington Street, Cambridge.*
Apr. 14		Samuel Marcus	Russell, *Imperial Maritime Customs, Foochow, China.*
Apr. 12	*	Sir David L.	Salomons, Bart. M.A., *Broomhill, Tunbridge Wells.*
Feb. 12	*	Ralph Allen	Sampson, M.A. F.R.S., *Observatory House, Durham.*
Feb. 14		Charles F.	Sandberg, M.A., *Sherborne, Dorset.*
Nov. 9	*	Samuel Arthur	Saunder, M.A., *Wellington College;* and *Fir Holt, Crowthorne, Berks.*
Jan. 14	*	Harris C. L.	Saunders, *Stratford Lodge, Twickenham.*

Date of Election.		
1866 May 11	* James Ebenezer	Saunders, F.G.S. F.L.S. F.S.A., 4 *Coleman Street, E.C.*
1895 Dec. 13	Herbert	Savery, M.A., *The College, Marlborough, Wilts.*
1869 Jan. 8	* Samuel	Saywell, M.A. F.L.S., *The College, Bromsgrove, Worcestershire.*
1889 Jan. 11	* William	Schooling, 25 *Westminster Palace Gardens, S.W.*
1877 Dec. 14	* Arthur	Schuster, Ph.D. F.R.S., Professor of Physics in Owens College (Victoria University), *Victoria Park, Manchester.*
1891 Jan. 9	James Lidderdale	Scott, *care of Scott, Harding, & Co., P.O. Box 120, Shanghai, China.*
1870 Apr. 8	George Mitchell	Seabroke, Temple Observer, *Rosemont, Rugby.*
1893 Nov. 10	* Thos. Jefferson J.	See, Ph.D., Professor of Mathematics in the U.S. Naval Observatory, *Georgetown Heights, Washington, D.C., U.S.A.*
1891 Jan. 9	* Arthur Laidlaw	Selby, M.A., *University College of South Wales and Monmouthshire, Cardiff;* and 3 *Palace Road, Llandaff, Cardiff, South Wales.*
1897 Jan. 8	Beauchamp Prideaux	Selby, J.P., *Pawston, Cornhill-on-Tweed, Northumberland.*
1884 Dec. 12	Harold	Seward, B.A., *Patent Office, Southampton Buildings, Chancery Lane, W.C.*
1861 Jan. 11	Philip E.	Sewell, *Gurney's Bank, Norwich.*
1899 Mar. 10	Col. Thos. Davies	Sewell, 29 *Grosvenor Road, S.W.*
1900 Dec. 14	Capt. Ernest H.	Shackleton, *care of Dr. Shackleton, Aberdeen House, West Hill, Sydenham, S.E.*
1893 Dec. 8	* William	Shackleton, 1 *Eridge Road, Bedford Park, W.*
1892 June 10	* Martin Charles	Sharp, M.A., *Cintra, Hampstead Lane, Highgate, N.*
1890 June 13	Thomas Steele	Sheldon, M.B.Lond., *Parkside, Macclesfield.*
1878 Apr. 12	* Rev. Alfred J. P.	Shepherd, B.A., *The Rectory, Sulhampstead, Reading.*
1891 Jan. 9	* Rev. Walter	Sidgreaves, S.J., *Stonyhurst College Observatory, Blackburn, Lancashire.*
1857 Mar. 13	* James	Simms, 138 *Fleet Street, E.C.*
1851 Jan. 10	* William	Simms, *Albert Lodge, Hope Road, Shanklin, Isle of Wight.*
1890 Apr. 11	Andrew	Simons, F.G.S. F.R.G.S., *Lavernock, Emsworth, Hants.*
1894 June 8	David Goudie	Simpson, 199 *Camberwell Grove, Denmark Hill, S.E.*
1892 Jan. 8	John Samuel	Slater, Professor of Civil Engineering, Civil Engineering Coll., *Seebpore, Calcutta, India.*
1897 Apr. 9	John Sisson	Slater, M.A. LL.D., 1 *Garden Court, Temple, E.C.*; and *Seafield, Lytham Lancashire.*

of Election.			
Jan. 11	*	Rev. Philip R.	Sleeman, 65 *Pembroke Road, Clifton, Bristol.*
Dec. 13	*	David	Smart, M.R.C.S. L.R.C.P. L.S.A., 108 *Grange Road, Bermondsey, S.E.*
Mar. 8		Rev. Maurice A.	Smelt, M.A., *Heath Lodge, Cheltenham.*
May 9	*	Charles Michie	Smith, B.Sc. F.R.S.E., Government Astronomer, *Observatory, Kodaikánal, Palani Hills, South India.*
June 8		Rev. E. Harrison	Smith, M.A. R.N. (*No address: see slip*).
Feb. 14		George Albert	Smith, *St. Ann's Well, Brighton.*
April 10	*	Geo. Fredk. Herbt.	Smith, M.A. F.G.S., *British Museum of Natural History, Cromwell Road, S.W.*
Apr. 12	*	John Bagnold	Smith, *Newstead Colliery, near Nottingham.*
Jan. 9		John Peter Geo.	Smith, *Sweyney Cliff, Coalport, R.S.O., Shropshire.*
Jan. 9	*	Rev. William	Smith, *The Manse, Tower Hill, Bromyard, viâ Worcester.*
Feb. 12		William Arthur	Smith, 154 *Hagley Road, Edgbaston;* and 94 *Charlotte Street, Birmingham.*
Nov. 8		Monroe B.	Snyder, Director of the Philadelphia Observatory, *Philadelphia, Pa., U.S.A.*
June 10		William Edward	Sparkes, 8 *Claremont Terrace, Sunderland.*
Mar. 8		Rev. Danl. Higham	Sparling, B.A. (*No address: see slip*).
Apr. 9		Rev. John	Spence, 13 *Elm Park Road, Chelsea, S.W.*
Jan. 10	*	Charles Tallent	Spencer, A.M.Inst.C.E., *The Hall, Harmondsworth, Middlesex.*
Jan. 12		EDMUND J.	SPITTA, L.R.C.P. Lond., VICE-PRESIDENT, *Ivy House,* 31 *South Side, Clapham Common, S.W.*
Feb. 13	*	W. W. Spencer	Stanhope, *Cannon Hall, Barnsley, Yorkshire.*
Feb. 9		William Ford	Stanley, F.G.S. F.R.Met.Soc., *Cumberlow, South Norwood, S.E.*
Feb. 13		Captain John	Steele, *The Rectory, Flordon, near Norwich.*
May 8		Capt. Buckenham	F. Stevens, *Letts Green, Knockholt, Sevenoaks, Kent.*
Feb. 10	*	Charles	Stevens, 10 *Wemyss Road, Blackheath, S.E.*
Mar. 8		Frederick Haller	Stevens, B.A., *Clifton College, Bristol.*
Dec. 11		Capt. Geo. Richd.	Stevens, *Hong Kong, China.*
Jan. 13	*	Robert Norton	Stevens, *Woodham Hall, near Woking Station, Surrey.*
Mar. 14		John Torrens	Stevenson, *Nelson Street, Auckland, New Zealand.*
Mar. 9	*	Rev. Walter Edw.	Stewart, M.A., *Elcott House, Hurworth-on-Tees, Darlington.*
May 11		William Stewart	Stewart, *Levern, Barrhead, Scotland.*
June 8	*	Sir John Benjamin	Stone, M.P. J.P. F.L.S. F.G.S. F.R.G.S., *The Grange, Erdington, near Birmingham.*

Date of Election.			
1860 Feb. 10	*	G. Johnstone	Stoney, M.A. D.Sc. F.R.S., 30 *Ledbury Road, Bayswater, W.*
1861 Jan. 11		John Matthew	Stothard, M.D., *Laurel Lodge, Monkstown, Co. Dublin, Ireland.*
1869 Mar. 12	*	Lt.-Col. George	Strahan, R.E., *Dehra Dûn, N.W.P., India.*
1892 Nov. 11		Edward	Stroud, *Coopers' Company's School, Tredegar Square, Bow;* and 74 *Marquess Road, Canonbury, N.*
1901 May 10		Rev. Edw. John	Stutter, O.S B., *Acton Burnell, near Shrewsbury.*
1898 Jan. 14	*	Ambrose	Swasey, *Cleveland, Ohio, U.S.A.*
1879 Apr. 9		Lewis	Swift, *Marathon, Cortland Co., N.Y., U.S.A.*
1890 Jan. 10	*	Hy. Wm. Lloyd	Tanner, D.Sc. F.R.S., Professor of Mathematics in the University College of South Wales and Monmouthshire, 14 *Llanbleddian Gardens, Cardiff, South Wales.*
1889 Feb. 8		Kenneth James	Tarrant, *Craven Cottage, Bushey Heath, Herts;* and 63 *Threadneedle Street, E.C.*
1892 Nov. 11	*	John	Tatlock, Jun., M A., *P.O. Box* 194, *New York City, U.S.A.*
1888 Dec. 14	*	Albert	Taylor, *Gorphwysfa, Cwrt-y-Fil Road, Penarth, South Wales.*
1898 Mar. 11		Alfred	Taylor, *c/o T. Cooke & Sons, Buckingham Works, York;* and *Polvellan, Holgate Hill, York.*
1894 Dec. 14		Basil R. H.	Taylor, Assis. Harbour Master, *Hong Kong, China.*
1896 Feb. 14		Charles Albert	Taylor, 56 *Ramsden Road, Balham, S.W.*
1885 May 8	*	C. H. Brewitt	Taylor, *care of I.M. Customs, Shanghai, China.*
1899 Dec. 8		Clement Jennings	Taylor, *Derby Villa, Derby Road, Kenilworth, Cape Town, S. Africa.*
1875 May 14	*	Henry Martyn	Taylor, M.A. F.R.S., *Trinity College, Cambridge.*
1886 Dec. 10		Washington	Teasdale, F.R.M.S., *Headingley, Leeds.*
1873 Jan. 10		John	Tebbutt, *Observatory, Windsor, New South Wales.*
1855 June 8	*	Lt.-Gen. Jas. F.	Tennant, C.I.E. R.E. F.R.S., PAST PRESIDENT, 11 *Clifton Gardens, Maida Hill, W.*
1874 Nov. 13	*	Dr. François	Terby, 96 *rue des Bogards, Louvain, Belgium.*
1881 Mar. 11	*	Rev. Thomas R.	Terry, M.A., *The Rectory, East Ilsley, near Newbury, Berks.*
1890 Jan. 10		Wm. Grasett	Thackeray, *Royal Observatory, Greenwich;* and 15 *Shooter's Hill Road, Blackheath, S.E.*
1888 May 11		Sir Henry	Thompson, Bart., F.R.C.S. M.B.Lond., 35 *Wimpole Street, W.*
1880 June 11	*	Capt. Peter	Thompson, 26 *Westmount Road, Eltham, Kent.*

Election.			
May 14		Silvanus Phillips	Thompson, B.A. D.Sc. F.R.S., Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, *Morland, Chislett Road, West Hampstead, N.W.*
Jan. 9	*	Capt. Benjamin	Thomson, Lieut. R.N.R., *Littlecroft, Chiddingfold, Surrey.*
Feb. 12		Wm. Henry	Thornthwaite, *St. Mildred's House, Poultry, E.C.;* and *Claremont House, Hersham, Walton-on-Thames, Surrey.*
Jan. 8		Arthur	Thornton, M.A., *The Grammar School, Bridlington, Yorkshire.*
Apr. 11		Thomas	Thorp, *Moss Bank, Whitefield, near Manchester.*
Feb. 12	*	Christopher	Thwaites, M.I.C.E., *Burnell Rd., Sutton, Surrey.*
Apr. 8		Capt. W.	Tillar, *St. Hilda's, Westbourne Road, West Kirby, Cheshire.*
Feb. 10		William Harold	Tingey, B.A. F.R.Met.Soc., *Rede Court, Rochester, Kent.*
Apr. 8		Sir Charles	Todd, K.C.M.G. M.A. F.R.S., Government Astronomer, *Observatory, Adelaide, South Australia.*
Feb. 10	*	Captain Henry	Toynbee, 12 *Upper Westbourne Terrace, W.*
Jan. 8	*	Julien	Tripplin, 31 *Holborn Viaduct, E.C.;* and 23 *Heathfield Gardens, Chiswick, W.*
Dec. 11		John Burt	Trivett, Assistant Government Statistician and Actuary to the Public Service Board, *Government Statistician's Office, Sydney, N.S.W., Australia.*
May 8	*	Lieut.-Col. G. L.	Tupman, R.M.A., *Hillfoot Observatory, College Road, Harrow.*
Jan. 9	*	HERBERT HALL	TURNER, D.Sc. F.R.S., PRESIDENT, Savilian Professor of Astronomy, Oxford, *University Observatory, Oxford.*
Jan. 10		Rev. C. Lakeman	Tweedale, M.A., *The Vicarage, Weston, near Otley, Yorks.*
Nov. 11		Edward	Tyer, *Ashwin Street, Dalston, E.*
June 8		Wm. John Vernon	Vandenbergh, F.R.Met.Soc., *care of G. B. Smith, 6 Malvern Road, Hornsey, N.*
Apr. 12	*	Frederick Henry	Varley, 82 *Newington Green Road, Islington, N.*
Jan. 14		John	Vaughan, Lieut. R.N.R. (*No address: see slip*).
Jan. 11		Rev. George	Venables, *Burgh Castle Rectory, near Great Yarmouth.*
Feb. 8		Rev. George	Vickars-Gaskell, *Grange-over-Sands, N. Lancashire.*
Feb. 11		James George	Vine, 35 *Glen Eagle Road, Streatham, S.W.*

Date of Election.			
1879 Nov. 14		Henry T.	Vivian, *Eversley, Winchfield, Hants.*
1895 Jan. 11		Rev. Peter Hately	Waddell, D.D., *The Manse, Whitekirk, Prestonkirk, Scotland.*
1901 May 10	*	Rev. Ernest Geo.	Wainwright, M.A., Vice-Principal, *The Training College, Winchester.*
1891 Jan. 9	*	Arthur John	Walker, M.A., *Mount St. John, Thirsk, Yorks*
1903 Apr. 8		Gilbert Thomas	Walker, M.A., *Meteorological Office, Simla, I*
1883 Jan. 12	*	William Henry	Walmsley, B.Sc., '*Nautical Almanac*' O 3 *Verulam Buildings, Gray's Inn, W.C.*
1902 Feb. 14		Albert	Walter, *Royal Alfred Observatory, Mauriti*
1888 May 11		John	Walther, M.D. C.M. F.R.Met. Soc., 109 *Ma St. Leonards-on-Sea.*
1863 Feb. 13		Col. M. Foster	Ward, *Bannerdown House, Batheaston, S set;* and *Partenkirchen, Bavaria.*
1888 Jan. 13	*	Francis James	Wardale, *The Limes, Shrewton, S.O., Wilt*
1899 Jan. 13	*	Worcester R.	Warner, *Cleveland, Ohio, U.S.A.*
1887 June 10	*	Hy. Addenbrook	Wassell, *Addenbrook Villa, Love Lane, S bridge.*
1876 Dec. 8	*	Major-Gen. James	Waterhouse, Bengal Staff Corps, *Oak L Court Road, Eltham, Kent.*
1884 Feb. 8	*	Frederick William	Watkin, B.A., *St. Paul's School;* and 43 *B Street, West Kensington, W.*
1870 Mar. 11	*	Rev. Hy. Charles	Watson, M.A., *Gainford Vicarage, Darlin*
1885 Apr. 10	*	Lt.-Col. Harry J.	Watson, *The Ridges, Farnborough, Hants.*
1897 Jan 8		John	Watson, *Halton View, 3 Wilson Patten S Warrington, Lancashire.*
1892 Jan. 8		Wm. Livingstone	Watson, *Ayton, Abernethy, Perthshire;* 105 *Pall Mall, S.W.*
1878 Jan. 11		Rev. G. E.	Watts, *Kensworth Vicarage, Dunstable, He*
1888 Feb. 10		Rev. W. R.	Waugh, *The Observatory, Portland, Dorse*
1879 Nov. 14	*	Robert Rumsey	Webb, M.A., *St. John's College, Cambridge.*
1875 June 11		Francis Richard	Wegg-Prosser, M.A., *Merry Hill House, ford;* and 20 *Alfred Place, Thurloe S S.W.*
1899 Feb. 10		Thomas	Weir, 56 *Parkfield Street, Moss Lane Manchester.*
1897 Feb. 12		Edward	Weldon, *Didmarton, Frant Rd., Tunbridge*
1901 Jan. 11		Richard	Welford, M.A., J.P., *Thornfield Villa, Gos near Newcastle-on-Tyne.*
1902 Apr. 11		William Boultbee	Whall, *Board of Trade, Linkside, Mussell Scotland.*
1877 Jan. 12	*	Rear-Adm. Sir W. J. L.	Wharton, K.C.B. F.R.S. F.R.G.S., H grapher for the Admiralty, *Florys, Pr Road, Wimbledon Park;* and *Athe* Club, Pall Mall, S.W.

Date of Election.		
1902 Feb. 14		Edward Fawcett White, Lecturer in Navigation and Nautical Astronomy, *Merchant Venturers' Technical College;* and *Wimborne House*, 31 *Ashley Road, Bristol.*
1869 Jan. 8	*	Edward John White, *Observatory, Melbourne, Victoria.*
1893 Mar. 10	*	Edward Turner Whitelow, 70 *Deansgate, Manchester.*
1898 Dec. 9		Charles Thomas Whitmell, M.A. B.Sc., *Invermay, Hyde Park, Leeds.*
1898 Feb. 11	*	EDMUND TAYLOR WHITTAKER, M.A., SECRETARY, *Trinity College;* and *Scotsdale*, 14 *Grantchester Street, Cambridge.*
1898 Feb. 11		Walter Wickham, *Radcliffe Observatory;* and 62 *St. John's Road, Oxford.*
1895 Jan. 11		Robert Wigglesworth, *York;* and 8 *Victoria Street, Westminster, S.W.*
1885 Dec. 11		Richard Wilding, *Dalwhinnie, Highland Road, Bromley, Kent.*
1899 Feb. 10		Algernon Chas. Legge Wilkinson, B.A., *Club of Western India, Poona, India.*
1903 Apr. 8		Pollard Wilkinson, B.A. B.Sc., 7 *Oban Street, Ipswich.*
1895 May 10		William Willett, Junr., *The Cedars, Chislehurst Common, Kent;* and 2 *Sloane Gardens, S.W.*
1884 May 9	*	Arthur Stanley Williams, *Bella Vista*, 20 *Hove Park Villas, Hove, Sussex.*
1865 Dec. 8	*	Harry Samuel Williams, M.A., 6 *Heathfield, Swansea, S. Wales.*
1875 Dec. 10	*	William E. Wilson, D.Sc. F.R.S., *Daramona, Streete, Rathowen, Ireland.*
1894 Jan. 12		Max Wolf, Ph.D., Professor der Astronomie an der Universität, *Astrophysikalisches Observatorium, Heidelberg, Germany.*
1877 Feb. 9	*	Arthur Mason Worthington, M.A. F.R.S., *R.N.E. College, Devonport;* and *Mohuns, Tavistock, Devon.*
1879 Jan. 10		Arthur W. Wright, Ph.D., Professor of Physics at Yale University, *New Haven, Connecticut, U.S.A.*
1867 Apr. 12	*	Stephen M. Yeates, 2 *Grafton Street, Dublin.*
1862 Dec. 12		Sir Allen Young, C.B., 18 *Grafton Street, Bond Street, W.*
1896 May 8		Alfred Ernest Young, Assoc.M.Inst.C.E., *Trigonometrical Survey of Perak, Taiping, Perak, Straits Settlements.*
1877 Jan. 12	*	Jesse Young, F.R.G.S., *Wisbech, Cambridgeshire.*
1898 Jan. 14		Thomas Emley Young, B.A., 108 *Evering Road, Stoke Newington, N.*
1875 June 11		Prof. C. Venceslas Zenger, *Palais Lobkowitz 7/III. Prague, Bohemia.*

ASSOCIATES.

of Election.		
5 May 11	G. F. J. Arthur	Auwers, Ph.D., Professor, *Lindenstrasse* 91, *Berlin, S.W.*
3 Dec. 9	O.	Backlund, Directeur de l'Observatoire Central Nicolas, *Poulkovo, Russia.*
2 Nov. 10	H. G. van de Sande	Bakhuyzen, Professor in the University and Director of the Observatory, *Leiden, Holland.*
3 Dec. 9	Edward Emerson	Barnard, D.Sc. F.R.A.S., *Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.*
0 Dec. 12	Lewis	Boss, Professor, Director of the Dudley Observatory, *Albany, N.Y., U.S.A.*
4 Nov. 14	Theodor	Brédikhine, Emeritus Professor, Doctor of Astronomy, *Imperial Academy of Sciences, St. Petersburg, Russia.*
3 Dec. 9	Sherburne Wesley	Burnham, M.A. F.R.A.S., Professor of Practical Astronomy in the University of Chicago, 1945 *Orrington Avenue, Evanston, Ill., U.S.A.*
1 Nov. 8	William Wallace	Campbell, Sc.D. LL.D. Director of the Lick Observatory, *viâ San José, California, U.S.A.*
9 Nov. 8	Seth C.	Chandler, 16 *Craigie Street, Cambridge, Mass., U.S.A.*
8 Dec. 9	Colonel Gilbert	Defforges, Correspondant du Bureau des Longitudes, 12 *rue St. Gabriel, Caen, France.*
9 Nov. 8	Nils Christian	Dunér, Ph.D., Professor, Director of the Observatory, *Upsala, Sweden.*
2 Nov. 11	W. L.	Elkin, Ph.D., *Yale University Observatory, New Haven, Conn., U.S.A.*
5 May 11	Wilhelm	Förster, Professor, Director der Sternwarte, *Enckeplatz* 3*a*, *Berlin, S.W.*

Date of Election.		
1848 May 12	Johann Gottfried	Galle, Ph.D., Professor, *Kiez-Strasse* 17, *Po* *Germany.*
1899 Nov. 10	George E.	Hale, D.Sc. F.R.A.S., Director of the Yerk servatory, *Williams Bay, Wisconsin,*
1879 Jan. 10	Asaph	Hall, *Goshen, Connecticut, U.S.A.*
1899 Nov. 10	Friedrich Robert	Helmert, Ph.D., ordentliche Professor Universität, Berlin; Director des K preussischen Geodätischen Institut des Centralbureaus der Internationale messung, *Potsdam, Germany.*
1889 Nov. 8	Paul P.	Henry, Astronome à l'Observatoire, *Par*
1889 Nov. 8	Prosper M.	Henry, Astronome à l'Observatoire, *Par*
1878 Nov. 8	George William	Hill, Ph.D., *West Nyack, N.Y., U.S.A.*
1884 Nov. 14	Edward Singleton	Holden, M.A. Sc.D. LL.D., *U.S. M* *Academy, West Point, N.Y., U.S.A.*
1872 Nov. 8	Jules	Janssen, Membre de l'Institut et du des Longitudes, Directeur de l'Obser d'Astronomie Physique, *Meudon, S* *Oise, France.*
1892 Nov. 11	Jacobus Cornelius	Kapteyn, Ph.D. Professor of Astron the University, *Groningen, Holland.*
1899 Nov. 10	Friedrich	Küstner, Ph.D., Professor der Astrono der Universität und Director der Köni Sternwarte, *Bonn, Germany.*
1883 Nov. 9	Samuel Pierpont	Langley, LL.D., Secretary of the Smit Institution, *Washington, D.C., U.S.A*
1886 Nov. 12	Maurice	Loewy, Membre de l'Institut et du des Longitudes, Directeur de l vatoire de Paris, *l'Observatoire, Pa*
1894 Nov. 9	Albert A.	Michelson, Ph.D., Professor of Physic University, *Chicago, U.S.A.*
1872 Nov. 8	Simon	Newcomb, Professor, 1620 *P Street,* W *ton, D.C., U.S.A.*
1884 Nov. 14	Magnus	Nyrén, Ph.D., Astronom der Ste *Pulkowa, Russia.*
1883 Nov. 9	J. A. C.	Oudemans, Ph.D., Professor, *Utrecht,*

of Election.		
1 June 10	Edward Charles	Pickering, D.Sc., Professor, Director of the Observatory, *Harvard College, Cambridge, Mass., U.S.A.*
1 Nov. 9	Henri	Poincaré, Membre de l'Institut, Professeur à la Faculté des Sciences, 63 *rue Claude-Bernard, Paris.*
1 Nov. 8	Julius	Scheiner, Ph.D., Professor der Astrophysik an der Universität Berlin; Hauptobservator am Astrophysikalischen Observatorium, *Potsdam, Germany.*
2 Nov. 8	Giovanni Virginio	Schiaparelli, *R. Osservatorio di Brera, Milan.*
2 Nov. 11	Hugo	Seeliger, Ph.D., Professor der Astronomie an der Universität, Director der Königlichen Sternwarte, *München, Bavaria.*
2 Nov. 11	Hermann	Struve, Ph.D., Director der Universitäts-Sternwarte, *Königsberg, Germany.*
3 May 12	Otto	Struve, *Fahnstrasse* 8, *Karlsruhe, Baden, Germany.*
1 Nov. 9	Pietro	Tacchini, Professore, Direttore dell' Ufficio centrale di Meteorologia e Geodynamica, dell' Osservatorio del Collegio Romano ed annesso Museo, *Via del Caravita* 7, *Rome.*
Nov. 10	Juan M.	Thome, Director, Observatorio Nacional Argentino, *Cordoba, Argentine Republic.*
Nov. 8	Charles	Trépied, Directeur de l'Observatoire Astronomique, *Bouzareah, Algiers.*
Nov. 10	Hermann Carl	Vogel, Ph.D., Professor, Director des Königlichen Astrophysikalischen Observatoriums, *Potsdam, Germany.*
Nov. 9	Edmund	Weiss, Ph.D., Professor, Director der K.K. Sternwarte, *Wien* (*Währing*), *Austria.*
Jan. 9	Chas. Joseph Étienne	Wolf, Membre de l'Institut, Astronome de l'Observatoire, Professeur à la Sorbonne, 1 *rue des Feuillantines, Paris.*
Nov. 8	Charles A.	Young, Ph.D. LL.D., College of New Jersey, *Princeton, New Jersey, U.S.A.*

LIST OF PERSONS TO WHOM THE MEDALS OR TESTIMONIALS OF THE SOCIETY HAVE BEEN ADJUDGED.

(*The Gold Medal is in every case intended except where otherwise stated.*)

1823. Charles Babbage.
Johann Friedrich Encke.
Charles Rumker (*the Silver Medal*).
Jean Louis Pons (*the Silver Medal*).

1826. J. F. W. Herschel.
James South.
Wilhelm Struve.

1827. Francis Baily.
William Samuel Stratford (*the Silver Medal*).
Colonel Mark Beaufoy (*the Silver Medal*).

1828. Sir Thomas Macdougall Brisbane.
James Dunlop.
Caroline Herschel.

1829. Rev. William Pearson.
F. W. Bessel.
H. C. Schumacher.

1830. William Richardson.
J. F. Encke.

1831. Captain H. Kater.
Baron Damoiseau.

1833. George Biddell Airy.

1835. Lieut. M. J. Johnson.

1836. Sir J. F. W. Herschel.

1837. O. A. Rosenberger.

1839. Hon. John Wrottesley.

1840. Jean Plana.

1841. F. W. Bessel.

1842. P. A. Hansen.

1843. Francis Baily.

1845. Captain W. H. Smyth, R.N.

1846. George Biddell Airy.

1848. George Biddell Airy (*Testimonial*
John Couch Adams *do.*
F. W. Argelander *do.*
George Bishop *do.*
Lt.-Col. George Everest *do.*
Sir J. F. W. Herschel *do.*
P. A. Hansen *do.*
K. L. Hencke *do.*
John Russell Hind *do.*
U. J. J. Le Verrier. *do.*
Sir J. W. Lubbock. *do.*
M. Weisse. *do.*

1849. William Lassell.

1850. Otto Struve.

1851. Annibale de Gasparis.

1852. C. A. F. Peters.

1853. John Russell Hind.

1854. Charles Rumker.

1855. Rev. W. R. Dawes.

1856. Robert Grant.

1857. H. Schwabe.

1858. Rev. Robert Main.

1859. R. C. Carrington.

1860. P. A. Hansen.

1861. Hermann Goldschmidt.

. Warren De La Rue.
. F. W. Argelander.
. G. P. Bond.
. John Couch Adams.
. William Huggins.
W. A. Miller.
. U. J. J. Le Verrier.
. E. J. Stone.
. Charles Delaunay.
. G. V. Schiaparelli.
. Simon Newcomb.
. H. L. D'Arrest.
. U. J. J. Le Verrier.
. Baron Dembowski.
. Asaph Hall.
. Axel Möller.
. David Gill.
. B. A. Gould.
. A. A. Common.

1885. William Huggins.
1886. E. C. Pickering.
Charles Pritchard.
1887. G. W. Hill.
1888. Arthur Auwers.
1889. Maurice Lœwy.
1892. G. H. Darwin.
1893. H. C. Vogel.
1894. S. W. Burnham.
1895. Isaac Roberts.
1896. S. C. Chandler.
1897. E. E. Barnard.
1898. Wm. F. Denning.
1899. Frank McClean.
1900. Henri Poincaré.
1901. E. C. Pickering.
1902. J. C. Kapteyn.
1903. Hermann Struve.

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1897. Lewis Swift.
1902. Rev. Thomas D. Anderson.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

APPENDIX TO VOL. LXIII.

[*From Proceedings of the Royal Society, Vol. LXXI.*]

With indication of the original pagination.

No. 1.

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"Preliminary Note on the Relationships between Sun-spots and Terrestrial Magnetism." By C. CHREE, Sc.D., LL.D., F.R.S. Received December 18, 1902,—Read January 22, 1903.

(From the National Physical Laboratory.)

I have been engaged during the last two years on an analysis of the magnetic results obtained at Kew Observatory (now the National Physical Laboratory), during an 11-year period, 1890 to 1900. The work has been much interrupted, and is still incomplete. Amongst the points dealt with is the inter-relationship between sun-spot frequency and magnetic phenomena, and, as this has recently been engaging attention elsewhere, I have decided to put certain of my results on record at once. It has long been known from the researches of Balfour Stewart, Ellis, and others, that there is a close connection between the times of occurrence of greatest sun-spot frequency and largest amplitude of the diurnal inequality of magnetic declination and horizontal force. I have investigated whether the numerical relationship between the phenomena can be adequately represented mathematically in a simple way.

A convenient basis for the investigation was presented by the publication by Professor Cleveland Abbe in the 'U.S. Monthly Weather Review,' for November, 1901, of a table of sun-spot frequencies as calculated by Wolf and Wolfer for a very long series of years. After I had carried out all the calculations, Wolfer himself published a similar table* embodying his latest corrections. The differences from Abbe's table are trifling, and mainly confined to two years (1891 and 1892). I judged it best, however, to revise the whole of my arithmetic, so as to employ Wolfer's own most approved figures. In the following remarks S represents Wolfer's value for the sun-spot frequency. The above-mentioned table gives the mean S for each month and for each year.

The magnetic quantity selected for comparison is the mean monthly "range" [redacted]ning thereby the difference between the greatest and

* 'Met. Zeitschrift,' May, 1902 p. 185.

least of the twenty-four hourly values in the mean diurnal inequality for the month in question, based on the five *quiet* days selected for the month by the Astronomer Royal. Calling this quantity R for any particular magnetic element, I tentatively assumed

$$R = a + bS \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1),$$

with a and b constants. I grouped together the 11 Januarys, the 11 Februarys, and so on, of the 11-year period, and determined a and b by least squares for each of the resulting 12 groups. There being only 11 years' data, the calculated values doubtless are appreciably affected by quasi-accidental irregularities, but there is so striking a resemblance between the more conspicuous features of the results found for the declination, inclination and horizontal force as to justify the conclusion that the phenomena are *bonâ fide*. Full particulars will be given later. At present it will suffice to record the mean values found for the a and b of the formula for three groups of months —viz. :—

Winter, comprising November to February,
Equinox „ March, April, September, October, and
Summer „ May to August.

The results are as follows :—

Table I.

	Declination.		Inclination.		Horizontal force. (Unit $1\gamma \equiv 10^{-5}$ C.G.S.)		Vertical force. (Unit $1\gamma \equiv 10^{-5}$ C.G.S.)	
	a.	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*
Winter ...	3′·23	0′·0323	0′·63	0′·0105	10·5	0·161	7·0	0·032
Equinox ..	7 ·32	0 ·0478	1·26	0 ·0147	23·5	0·221	17·2	0·026
Summer ..	8 ·91	0 ·0428	1·61	0 ·0137	30·6	0·190	22·7	0·035
Mean.....	6 ·49	0 ·0410	1·17	0 ·0130	21·5	0·191	15·6	0·031

As is obvious from (1), a represents the amplitude of the range corresponding to a total absence of sun-spots. During the eleven years dealt with, Wolfer's mean monthly values for S varied from 0·3 to 129·2, the mean being 41·7.

To bring out more clearly the similarity of the results for the declination, inclination and horizontal force, I have represented the mean value of b for the 12 months in each element by 100. The corresponding values for the three seasons are, then, as follows :—

Table II.

	Winter.	Equinox.	Summer.
Declination	79	117	104
Inclination	81	113	106
Horizontal force.. ...	85	116	99

In obtaining these figures I have retained a figure in the value of b beyond that recorded in Table I.

Tables I and II will suffice to bring out one of the most important points established, viz., that b is certainly different from one month to another, and is, for all the elements except the vertical force, decidedly larger at the equinoxes (more especially it would appear at the spring equinox) than at other seasons. This means that the equinoxes are the seasons at which the amplitude of the diurnal inequality, when considered *absolutely*, is most dependent on the sun-spot frequency. When we take into account, however, the difference between the ranges of the diurnal inequalities at different seasons of the year, we find that winter is the season when sun-spot frequency is *relatively* most important. This will be recognised on reference to Table III, remembering that a represents the range corresponding to a total absence of sun-spots, while $a + 41{\cdot}7\,b$ is the range corresponding to a sun-spot frequency of 41·7, this being, as already mentioned, Wolfer's mean value for the 11 years in question.

Table III.

Values of $41{\cdot}7b \div a$.

	Declination.	Inclination.	Horizontal force.	Vertical force.
Winter	0·42	0·69	0·60	0·19
Equinox	0·27	0·49	0·39	0·06
Summer	0·20	0·35	0·26	0·07

Table III serves also to bring out another important result, viz., that the influence of sun-spot frequency on the amplitude of the diurnal inequality is very much less for the vertical force than for the three other elements considered.

A recent interesting paper by Rajna* shows that the idea of a linear relationship between diurnal magnetic range and sun-spot frequency has already been applied by at least two previous investigators, Rajna and Wolfer. They seem, however, to have applied it only to mean annual values, and to have considered declination only. Rajna, dealing with declination data, observed at Milan over the long period 1836 to 1901, applies a formula of type (1) to what he calls the "medie annuali dell' escursione diurna."

The value he finds for b is 0′·047. He mentions that in an earlier similar investigation, including declination data from several stations, Wolfer obtained the value 0′·040.

I am uncertain as to the precise meaning of Rajna's "medie annuali," but it certainly is not quite the same thing as the mean range in Table I, so that the results are not absolutely comparable.

* 'Rendiconti del R. Ist. Lomb.,' Ser.

Another recent and able paper bearing on the subject appears in the last published volume of the French Bureau Météorologique, which has just come into my hands. The author, Mr. Alfred Angot, has anticipated me in applying a formula of type (1) to the individual months of the year; but he treats of the amplitude, not of the diurnal range as a whole, but of that of the coefficients of the several terms of the Fourier's series into which the diurnal inequality can be analysed. The paper treats only of the declination—dealing with data from ordinary days at Parc St.-Maur, Greenwich and Batavia—but the author expresses his intention of considering in the future the horizontal force.

A special feature of the present investigation is that the magnetic data are derived exclusively from magnetic *quiet* days. This suggests at once a query and a criticism, a query as to why one did not employ corresponding sun-spot data confined to the magnetically quiet days, a criticism that as the two sets of data employed do not absolutely correspond, the comparison actually made may be misleading.

As to the query: Wolfer, it is true, publishes at regular intervals in the 'Met. Zeitschrift' *provisional* sun-spot frequencies for each day. These figures are, however, presumably inferior in certainty to the final figures he has embodied in his table after consulting all available sources of information. The vital consideration, however, is that at certain seasons of the year there are a number of days for which, owing to the absence of observations, Wolfer has no provisional sun-spot data. With information lacking for two or three out of the five quiet days of a month there would have been a very undesirable amount of uncertainty. As to the criticism, it would be difficult to meet it if it could be held that the enhanced magnetic activity existing at the earth's surface at times of sun-spot maxima is due directly to electrical disturbances in the sun, each disturbance being limited to regions where sun-spots exist, and only those disturbances being effective which happen to be at the moment on the half of the sun visible from the earth. At present I shall only mention the following fact:—I had monthly sun-spot frequencies calculated from Wolfer's *provisional* figures, employing only the five "quiet" days selected for each month by the Astronomer Royal. The mean sun-spot frequency thence deduced for the eleven years (1890 to 1900) differed from the corresponding result given by all Wolfer's days by less than one-fifth of 1 per cent. It is hardly necessary to point out that this fact has an important bearing, not only on the point immediately under consideration, but also on the further question as to the true nature of the connection between sun-spots and magnetic storms.

"The Relation between Solar Prominences and Terrest
netism." By Sir NORMAN LOCKYER, K.C.B., F.
WILLIAM J. S. LOCKYER, M.A., Ph.D., F.R.A.S.
January 14,—Read January 29, 1903.

(PLATES [1] AND [2].)

It has been stated in a previous communication* that a p
reduction of the Roman observations of prominences, obser
sun's limb by Tacchini, indicated that, in addition to mai
maxima and minima of prominences coinciding in time wi
the maxima and minima of the total spotted area, ther
prominent subsidiary maxima and minima.

One of us has pointed out in a recent communicat
Académie des Sciences † that a comparison of the fre
prominences visible in each solar latitude with the freque
most intense magnetic storms, indicated that (*a*) magn
classed as "great" by Ellis, and the greatest prominence ac
the poles of the sun occurred at the same time; and (*b*) tha
of general magnetic activity was nearly the same as
prominences observed near the solar equator.

The object of the present communication is to give a mo
account of the research so far as it has gone.

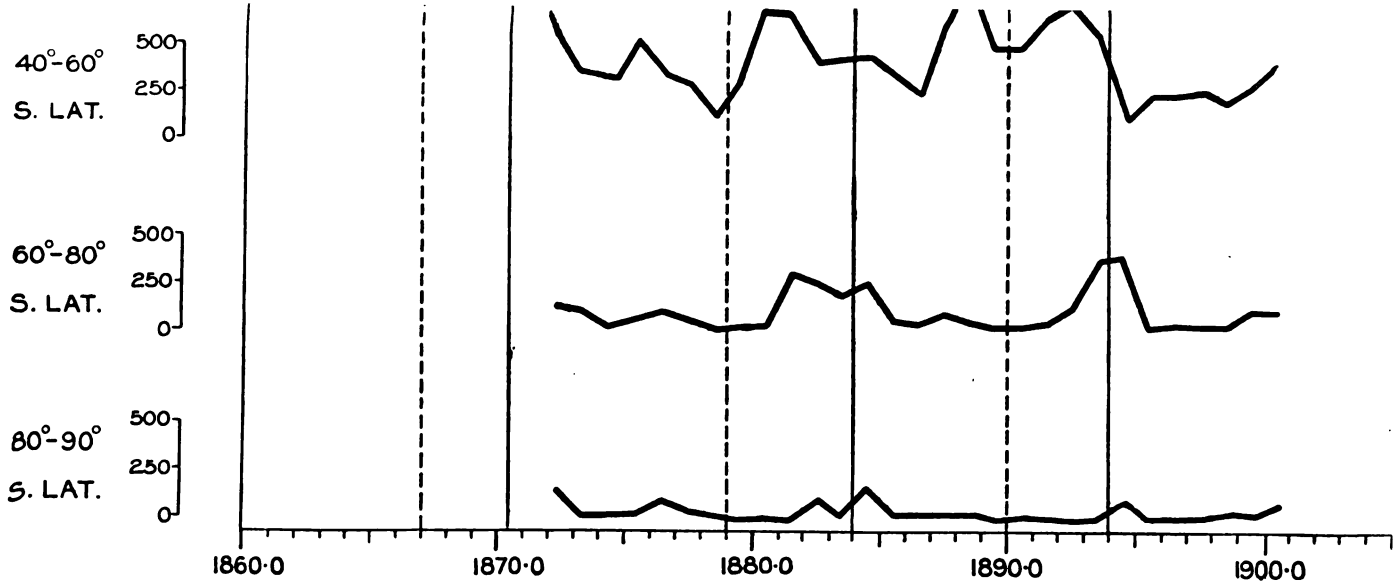
The Observations of Prominences.

The fine series of observations, made by Tacchini, of th
and latitudes of prominences seen on the sun's limb was
basis for the curves discussed. These observations were
in 1872, and have been continued up to the present day,
have a valuable continuous record. They have been publi
time to time in full detail, thus rendering it possible to deal
in any manner that may be desired. In the reduction of
tions each zone of 10° was examined and discussed by i
observations were divided in the first instance into grou
months, and the percentage frequency of the prominences
mined by dividing the number observed by the number
which observations were made in this period.

In this way a set of eighteen curves, nine for each hemis
made, showing the variation from year to year of the
frequency of prominence activity in each ten-degree zone.

* 'Roy. Soc. Proc.,' vol. 70, p. 502.

† 'Comptes Rendus,' vol. 135, No. 8, 25th August, 1902.
'Società degli Spettroscopisti Italiani,' vol. 1, 1872; vol. 29,



Curves showing the percentage frequency of solar prominences for each 20° zone N. and S.
(The continuous and broken vertical lines indicate the epochs of sun-spot maxima and minima respectively.)

In the curves accompanying the present communication (Plate [1]) the above-mentioned set, except those for 80°—90° north and south, have been grouped in pairs, thus representing the percentage frequency of prominences in each hemisphere for zones of 20° of latitude, 0°—20°, 20°—40°, &c., since it was found that this reduction could be made without losing any of the characteristic variations.

An examination of these curves shows that they differ very considerably one from the other as we proceed from the equatorial to the polar zones. Generally speaking the curves representing the variations for each of the zones, 0°—20° north and south, conform with the sun-spot curve; that is, the maxima and minima occur at about the epochs of sun-spot maxima and minima. Those for the two zones, 20°—40°, in both hemispheres conform also in the main to the general sun-spot curve, but in addition they display subsidiary maxima or changes of curvature superimposed on the main curve.

The curves for the two zones, 40°—60° north and south, have, on the other hand, hardly any likeness to the sun-spot curve, but are made up of a series of prominent maxima representing special outbursts of prominence activity.

Passing to the curves corresponding to the next zones, *i.e.*, 60°—80° north and south, these indicate two prominent outbursts lasting for a short period, showing that this region of the sun is, as a rule, practically free from prominence activity; in the remaining zones, 80°—90° north and south, the variation is small, and is a faint echo of the condition of affairs in the neighbouring zone 60°—80°.

The Magnetic Curves.

The data regarding the magnetic phenomena employed in this comparison are those brought together by Mr. William Ellis, in two published papers on magnetic phenomena.*

We may take the opportunity here of thanking Mr. Ellis for kindly communicating to us a continuation of the data published in these two papers, which information he has brought down to the year 1899.

Two classes of magnetic phenomena were there dealt with, namely, the variations from year to year of the diurnal range of the declination and horizontal force, and magnetic disturbances.

As regards the former, Mr. Ellis has shown† that the curves indicating these variations are very similar to that of the general sun-spot curve; in fact, the curves were found to be almost identical in all their smaller irregularities.

* 'Phil. Trans.,' Part II, 1880, "On the Relation between the Diurnal Range of Magnetic Declination and Horizontal Force, as observed at the Royal Observatory, Greenwich, during the years 1841 to 1877, and the Period of Solar Spot Frequency"; 'Monthly Notices, R.A.S.,' December, 1899, vol. 60, No. 2, "On the Relation between Magnetic Disturbance and the Period of Solar Spot Frequency."

† 'Phil. Trans.,' Part II, 1880.

The second class of phenomena, namely, the magnetic disturbances; which are more irregular in occurrence, has been classified by Mr. Ellis into five groups, and tabulated by him under five separate subheads. For the present paper, reference will only be made to one of these classes, namely, that described as "great," this group representing the largest disturbances. The curve representing the variation in number of these disturbances indicates short intermittent crests, outbursts, in fact, with rapid rises to maxima and falls to minima, and comparatively long intervals of quiescence.

Comparison of the Curves representing Prominence Frequency and Variation of Diurnal Magnetic Range.

Mr. Ellis, as already has been pointed out, has indicated the close resemblance between the sun-spot curve and that representing the variation of the magnetic elements; and it has been shown in the earlier part of this paper, that the curves representing the percentage frequency of prominences near the solar equator, conform in the main to the general sun-spot curve.

There is therefore an apparent connection between phenomena occurring in the equatorial regions of the sun (as represented by zones of prominences near the equator, and sun-spots which are practically restricted to these zones), and the ordinary diurnal magnetic variation.

The accompanying set of curves (Plate [2]) illustrates the great similarity between those showing the frequency of prominences in a zone about the equator (0°—20° north and south) and the variations of the mean daily range of magnetic declination; for the sake of comparison, three other curves are added, showing the variation of the mean daily area of sun-spots for the whole, and the two hemispheres of the sun separately.*

* In referring to the curve representing the variation of the mean daily areas of sun-spots, it may be noted that this is obtained by combining the mean daily areas of both hemispheres of the sun. A closer analysis shows, however, that this variation is not the same for both hemispheres. From the year 1862, when such a division of the sun's disc can be easily investigated, the northern hemisphere, about the time of the two last maxima, displayed double maxima occurring in the years 1881 and 1884, and in the years 1892 and 1895. About the time of the maximum of 1870 this duplicity is not so marked, although when compared with the curve for the southern hemisphere for this period, there is a slight indication of a subsidiary crest in 1872. In the case of the curve representing the mean spotted area for the southern hemisphere alone, at all the three epochs of maximum, the curves are single-crested and indicate sharply-defined maxima in the years 1870, 1883, and 1893.

From the above it will be seen, therefore, that the actual epochs of sun-spot maxima, as determined from the northern and southern hemispheres respectively,

Comparison of the Prominences with the Magnetic Disturbance Curves.

If a comparison of the curve representing the number of days of the "great" magnetic disturbance is made with those representing prominence frequency (Plate [1]), it will be seen that the former is as unlike the curves representing the prominence frequency about the solar equator as it is like those near the poles; in fact, the polar prominence outbursts, and great magnetic disturbances occur almost simultaneously.

The peculiar form and general similarity of the curves can be best seen from the accompanying illustration (fig. 1). In the figure comparison is made between the epochs of the crossing of the known and unknown lines, the percentage frequency of prominences about the solar poles and Ellis' "great" magnetic disturbances.

Two curves representative of prominence frequency are given, one to indicate the abrupt nature of the curves representing the frequency in a zone near the pole 10 degrees in width (in this case 60°—70° north), and the second to illustrate polar action as a whole; this latter was obtained by making a summation of prominence frequency for the two zones 60°—90° north and south.

The simultaneous occurrence of the maxima suggests that, when the prominence action takes place at the polar regions of the sun, one effect on the earth is that we experience our greatest magnetic disturbances.

Further, according to Mr. Ellis,* "unusual magnetic disturbance is frequent about epochs of sun-spot maximum, and nearly or quite absent about epochs of sun-spot minimum."

We find that not only do these "great" disturbances occur at the same time as the polar prominences, but the spectroscopic observations of sun-spots show that they take place not only "about" the times of spot maximum, as stated by Mr. Ellis, but when the sun-spot curve is *approaching* a maximum and at the dates of the widened line crossings,† when the curve representing the "unknown" lines is on the rise, and crosses the "known" line which is descending. At the other epoch of "crossing," *i.e.*, when the curve showing the "known" lines is on the rise and the "unknown" is falling, there is practically no magnetic disturbance recorded. Attention is again drawn to these crossings, as it is desired to indicate that it is only at those particular times when the sun is increasing his temperature that these disturbances occur.

are not the same, and in dealing with the curve representing this variation for the whole hemisphere, this fact should be borne in mind.

It may further be noted that the epochs of minima may be practically considered the same for both hemispheres.

* 'Monthly Notices R.A.S.,' vol. 60, p. 148.

† 'Roy. Soc. Proc.,' vol. 67, p. 412.

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e facts in this paper explain why it is that magnetic storms some- take place when there are no spots, or no very large spots, on urface of the sun. Since the occurrence of magnetic storms is

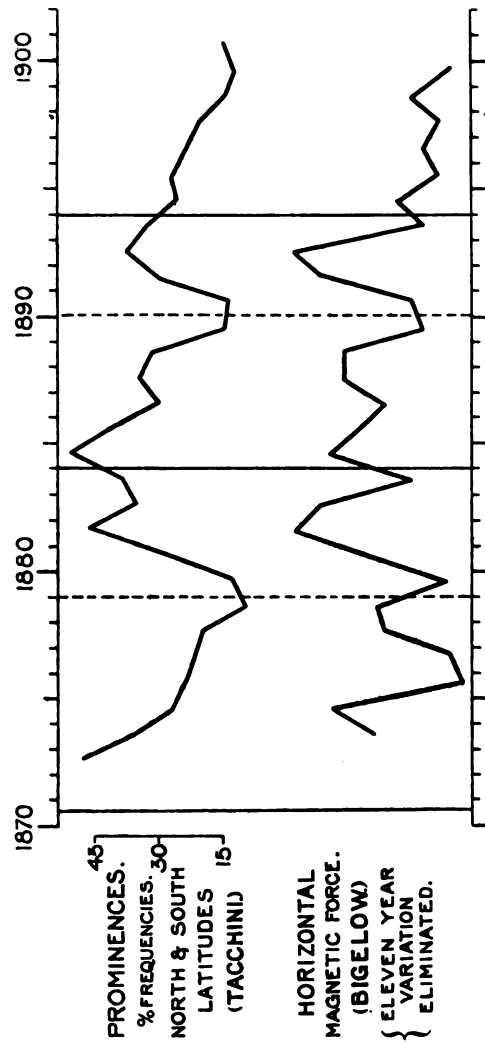

FIG. 2.—Comparison between horizontal magnetic force (Bigelow) and solar prominences (Tacchini). (Continuous and broken vertical lines as in fig. 1.)

n to be very closely connected with the solar prominences, there be prominences and magnetic storms when there are no spots. inences may also sometimes be associated with large spots, and as atter can be seen while the former can not, the resulting magnetic *is generally attributed* to the spots.

Further, the magnitude of magnetic storms appears to vary according to the particular position as to latitude of the prominence on the sun's disc. The nearer the poles (either north or south) the prominence occurs, the greater the magnetic storm, and these are the regions where no spots exist.

In this paper we have shown that the variations of the general magnetic phenomena, as given by Ellis, synchronise with the occurrence of prominences about the solar equator, while his "great" magnetic disturbances occur, in point of time, with the appearance of prominences in the polar regions of the sun.

Professor Bigelow has recently* investigated the variations in the horizontal magnetic force, and finds that the curve representing these changes exhibits subsidiary maxima which synchronise with those recorded in the curve representing the mean variation of prominences for all latitudes. Thus, to use his own words, "the remarkable synchronism between the curves cannot escape recognition, except after the year 1894, when an extra minor crest is developed in the horizontal force."

The accompanying diagram (fig. 2) gives Professor Bigelow's curve, which represents, as he says, "the series of minor variations which were found in the horizontal magnetic force . . . . after the 11-year cycle curve has been eliminated," together with the percentage frequency of prominences in all latitudes obtained by us from Tacchini's observations.

* 'Monthly Weather Review,' vol. 30, No. 7, July, 1902, p. 352.

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No. 2.

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Sir Norman Lockyer and Dr. W. J. S. Lockyer, Solar prominence and spot circulation, 1872—1901 . . . . . [14]

"Solar Prominence and Spot Circulation, 1872—1901." By Sir NORMAN LOCKYER, K.C.B., F.R.S., and WILLIAM J. S. LOCKYER, Chief Assistant, Solar Physics Observatory, M.A. (Camb.), Ph.D. (Gött.), F.R.A.S. Received March 17,—Read March 26, 1903.

(PLATES [3] AND [4].)

In our former communications* referring to the connection between solar, meteorological, and magnetic changes, some of the results obtained by the reduction of the solar prominences, as observed by Professor Tacchini at Rome, were described. It was stated that the curve representing the variation of percentage frequency of the prominences for the whole limb of the sun indicated that in addition to the main epochs of maxima and minima coinciding in time generally with those of the maxima and minima of the total spotted area, there were also prominent subsidiary maxima and minima.

Further, dividing the sun's limb into zones of 20° in width from the equator, with a polar zone of 10°, and discussing each zone separately, the variation of the prominence percentage frequency about the equator was found to be very different from that in the higher latitudes, the former changing with the spots, and the latter exhibiting sudden outbursts just previous to the epochs of sunspot maxima, followed and preceded by comparatively long intervals of quietude.

In the present communication, the prominence observations have been discussed from a different point of view, in order to trace out, if possible, the heliographic latitudes of the chief centres of action of prominence disturbance. In this way it could be determined whether such movements are subject to some periodic law, in which case it would be possible to increase our knowledge of the circulation of the solar atmosphere in regions outside those in which sunspots alone have, up to the present, been employed.

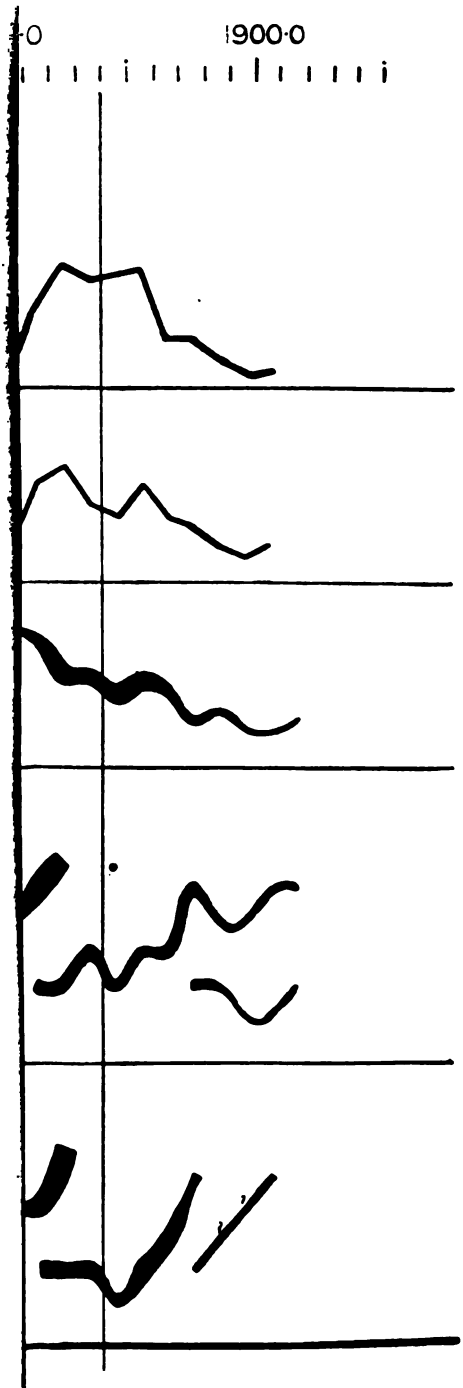
The changes of latitude of the zones which contain the centres of sunspot disturbances were first pointed out by Carrington,† whose fine series of observations led him to discover "a greater contraction of the limiting parallels between which spots were formed for the two years previous to the minimum of 1856, and soon after this epoch the apparent commencement of two fresh belts of spots in higher latitudes north and south, which have in subsequent years shown a tendency to coalesce, and ultimately to contract as before to extinction."

The study of the subject was taken up later by Spoerer,‡ who

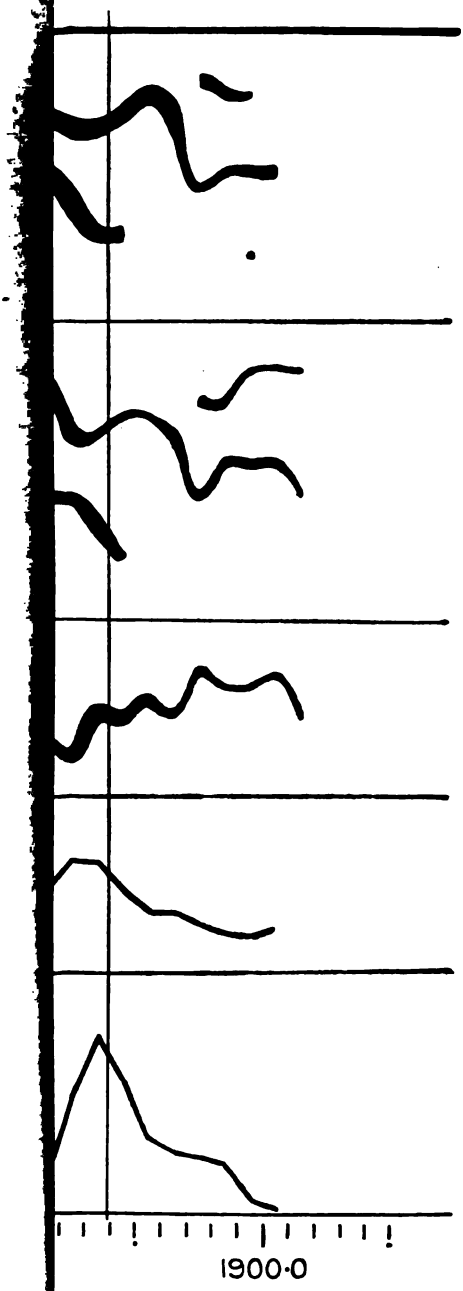
* 'Roy. Soc. Proc.,' vol. 70, p. 502; vol. 71, pp. 134 and 244.

† 'Observations of the Spots on the Sun from November 9, 1853, to March 24, 1861, made at Redhill,' p. 17.

‡ 'Beobachtungen der Sonnenflecken von Oct., 1871—Dec., 1873, und von Jan.,



nd B) and Spots (C), Percentage Frequency



to. Vertical lines same as on Plate 1.

corroborated Carrington's results and extended the discussion of the observations up to the end of the year 1879.

The result of these two investigations showed that at sunspot maximum there was only one zone in each hemisphere in which spots were situated, the centre of this being about 18° N and S, while at minimum there were two zones existing simultaneously in each hemisphere; the older cycle dying out in the zone, the centre of which was situated in low latitudes, and the new one commencing in high latitudes, its centre being about latitude $\pm 30°$ to $\pm 35°$.

Later observations extending up to the present year have further corroborated these general deductions, for each hemisphere, and we are now quite familiar with this cycle of sunspot latitude variation.

In the present investigation, the fact has been brought out that the prominences also undergo an apparently regular variation of latitude throughout a period of about eleven years concurrently with the spots.

For the purpose of our inquiry, the object of which has been stated above, we have discussed independently of each other, two fine series of prominence observations, one made by Tacchini at Rome extending from 1872 to 1900, and the other by Ricco and Mascari at Catania from 1881 to 1901.

Both these series were handled in the same way, and both indicated similar changes of latitude of prominence action, showing that the variations recorded were real and not due to any personality of the observer or difference in the method of observation.

The data for the discussion of the solar prominences as observed by Tacchini have been taken from the same source as before,* while those of Ricco and Mascari are published in and have been extracted from the same volumes.

We may here take the opportunity to express our thanks to Professor Ricco, with whom we have been in communication, and who has very kindly forwarded for our use some unpublished data concerning his prominence observations and reductions.

The method of reduction adopted was to determine for each year the percentage frequency of prominence activity for every 10 degrees of solar latitude north and south. A series of curves was next drawn, one for each year, the abscissæ representing the latitudes of prominences north and south, and the ordinates their percentage frequency. It was then found that the centres of prominence activity, or, in other words, the maxima of the curves, were sometimes single, sometimes double, and in one or two cases even triple in each hemisphere. This suggested that just as sometimes there are two

1874—Dec., 1879.' 'Publicationen des Astrophysikalischen Observatoriums zu Potsdam,' Band I and II.

* 'Società Spettroscopisti Italiani, vol. 1, 1872, to vol. 29, 1900.

zones of spots existing at one time, so there might be one, two, or occasionally three zones of prominences in existence in each hemisphere simultaneously.

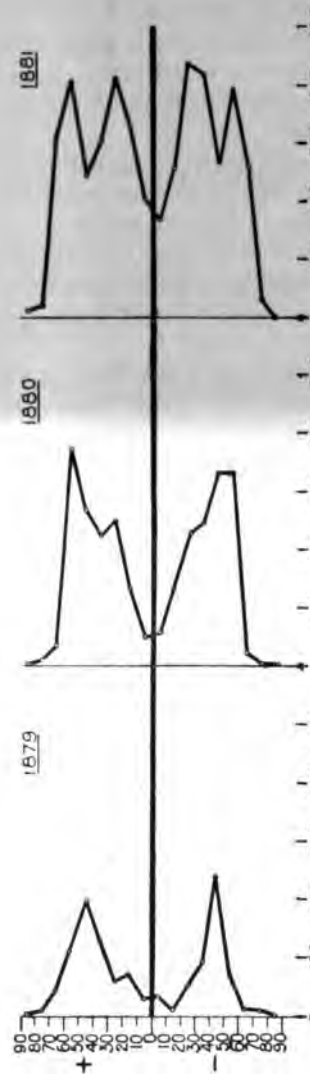


FIG. 1.—Curves showing the variation of the percentage frequency of prominence activity for every 10° of latitude for the years 1879—1881, from Tacchini's observations.

Further, a close examination of the whole set of curves with reference to these points of maxima made it possible not only to study the changes of latitude of these points from year to year and their positions when commencing to develop or about to disappear, but the intensity of these centres in relation to each other.

The accompanying illustration (fig. 1) shows the curves drawn for the years 1879, 1880, and 1881, from the observations of Tacchini, and serves as an example of the curves that have been discussed; they exhibit the change from a single to a double centre of activity in each hemisphere.

Thus in 1879, there was a prominence maximum in each hemisphere at latitudes $\pm 50°$. In the next year (1880), both the maxima had retreated further away from the equator, namely to latitudes $\pm 60°$, while another centre of disturbance began to make itself apparent at latitudes $\pm 30°$. In the year 1881, both centres in each hemisphere were strongly marked and became of about the same intensity, their mean latitudes in each hemisphere being about $\pm 30°$ and $\pm 60°$. These curves thus indicate that during these three years, the direction of motion of these centres of activity tends polewards or away from the equator.

By examining both series of observations made by Tacchini and Ricco and Mascari, and analysing the positions of the principal and

subsidiary maxima for the whole period covered by the observations, the results illustrated graphically in Plates [3] and [4] were obtained.

In these figures the facts are brought together for each hemisphere separately. The medials of the lines (curves A and B) show the heliographic latitudes of the centres of prominence action; the thickness of these lines represents the relative percentage frequency of prominence action.

For the sake of comparison, three other curves for each hemisphere are given. The first (curve C) shows the mean heliographic latitude of spotted area for each hemisphere. For the construction of these, the values, since 1873, have been extracted from the Greenwich Reductions,* but previous to that date the values have been obtained from Mr. Marth's reductions,† and those completed at the Solar Physics Observatory from measures supplied by Professor Backlund, of the Wilna Observatory.

The next curve (curve D) illustrates the variations of the percentage frequency of prominence action for each hemisphere taken, as a whole, and is similar to those given in our former papers.

The last curve (curve E) shows the variation of the mean daily area of sunspots from year to year, also for each hemisphere.

Referring now to the changes of latitude of the prominence centres of activity, both series of curves for the north as well as for the south hemisphere exhibit the same general features.

The first conclusion illustrated by the curves is that prominence activity in the main has a poleward drift, that is, the change of position of the zones of activity is in the direction from low to high latitudes. In some years, the centres of activity appear to form two zones in each hemisphere at about latitudes $\pm$ 24° and $\pm$ 50°, which eventually amalgamate at about latitude $\pm$ 40° and move polewards, fading out in about $\pm$ 70° to $\pm$ 80°. As this zone disappears in high latitudes a new zone at about latitude $\pm$ 20° begins, and this after a few years becomes associated with another zone in about latitude $\pm$ 50°, and eventually amalgamates with it.

The epochs at which these different zones come into play in relation to the general curve of prominence activity for the whole hemisphere are as follows: From a little after the maximum of prominence activity to just before the minimum, two zones in the latitudes $\pm$ 24° and $\pm$ 50° are in existence and of decreasing intensity. Before the minimum is reached these two zones amalgamate in about latitude $\pm$ 40°. At the minimum there is only one zone, and this of small intensity. Between the minimum and the following maximum this zone rapidly takes a northern movement, increasing in intensity; a new outburst

* 'Spectroscopic and Photographic Observations made at Royal Observatory, Greenwich, 1884,' and after.

† MSS. at Royal Society.

occurs in a zone nearer the equator (latitude ± 24°), which also increases rapidly in intensity.

After these general statements, we now refer to some details showing that there are some variations from the above generalisation.

For these details the curves deduced from both sets of observations made by the different observers are so very similar that it does not matter which are examined.

Attention may first be drawn to certain differences between the curves representing the latitude variation for the two hemispheres. It will be noticed that for the period 1872—1882, the curves for both hemispheres are very similar. We next consider the period 1880—1893. Here there are differences between the two hemispheres. The curve for the northern hemisphere resembles very closely that for the preceding period, but it differs somewhat from its corresponding curve for the southern hemisphere. The corresponding northern zone in latitude 45° is missing from the southern hemisphere, while a zone of activity nearer the equator about latitude 24° is present. Further, the polar zone for the southern hemisphere continues to be prominent for two years longer than that in the opposite hemisphere.

In the succeeding curves, which extend from 1891—1901, both hemispheres are more or less similar, and both resemble in a greater degree those for the southern hemisphere for the period 1880—1893 than those for the period 1872—1882.

Although the Roman and Sicilian observations give nearly identical curves, hemisphere for hemisphere, the apparently regular cycle of change of latitude which was operative for the northern hemisphere 1872—1893, and for the southern hemisphere 1872—1882, does not seem to have been so exactly maintained in late years; more irregular still perhaps is the last cycle commencing in the year 1892. Hence, there seems reason to believe that the prominence circulation is not quite the same for each cycle, and this may in some way be due to a longer solar period such as that of about 35 years.

But it is important to state that our deductions may be partially incomplete owing to the difficulty of determining sometimes whether a new centre of action has been formed or the position of an old one changed. Further, account must be taken of the fact that the material discussed does not represent the record of the percentage frequency of prominences determined from observations made on the disc of the sun (now rendered possible by the Janssen-Hale-Deslandres method), but one obtained from observations of the phenomena occurring only at the limb of the sun. The close agreement between the observation of the different observers shows nevertheless that this latter method is of great value.

Another important series of prominence observations is that made

by Father A. Fényi, S.J., who has published* the individual observations, and the reductions of the positions and frequency of prominences observed at Haynald Observatory for the years 1884 to 1890 inclusive. He gives curves constructed somewhat after the manner adopted in the present inquiry, as illustrated above, in fig. 1. A comparison of the points of maxima from his curves with those of Tacchini and Ricco and Mascari for the period common to all three sets of observations is made in the following tables, each hemisphere being given separately. The vertical columns show, for each year, the heliographic latitudes of the points of maxima, and an asterisk (*) is placed against the one which is the more or most prominent in each hemisphere; when there are two, and they are of equal intensity, this symbol is attached to each, while in the case of only slight indications of maxima the latitude is inclosed in brackets.

Northern Hemisphere.

	1884.	1885.	1886.	1887.	1888.	1889.	1890.
Tacchini	50, *25	45, *25	45, *20	35	*35, 15	40	45
Ricco and Mascari	55, *20	55, *15	45, *25	30	35	45	45
Fényi	65, 45, *15	45, *25	45, *20	45	*40, 20	*43, 25	45

Southern Hemisphere.

	1884.	1885.	1886.	1887.	1888.	1889.	1890.
Tacchini ..	(75), *25, 5	25	35, *20	*45, 25	*45, 25	45	45
Ricco and Mascari	(85), *25, (5)	25	35	*45, 25	*50, *25	45	50
Fényi	(75), *35, *15	(50), 35, *10	*35, *10	*50, 30, 15	*50, 25	40	*50, 20

It will be seen that for these seven years, Fényi's results are in very close accordance with those deduced from the other two series of observations, thus generally endorsing those portions of the curves in Plates [3] and [4] covering this period.

It was mentioned in a previous paper† that the mean prominence curve for each hemisphere exhibited subsidiary maxima and minima. In the light of the present investigation, it is interesting to compare

* 'Publicationen des Haynald-Observatoriums, Kalocsa,' Heft VI, 1892, und VIII, 1902.

† 'Roy. Soc. Proc.,' vol. 71, p. 244.

this curve with that representing the changes of latitude of the zones of prominences. In every case, and for each hemisphere, the subsidiary maxima are coincident in time with the presence of two zones of prominences, each well-developed, while at the principal minima only one zone is in evidence.

We have already explained the fact that spots are restricted to a zone having its limits at latitudes ± 5° and ± 35°, while prominences occur all over the sun's disc, even up to the poles, and also that spots always commence their cycle in high latitudes (about ± 35°) and gradually approach the equator until within 5°, when a new cycle is commenced in high latitudes. Prominences on the other hand begin in comparatively low latitudes (about ± 24°), and finish their cycle near the poles.

A glance at the Plates [3] and [4] brings out the interesting fact that at sunspot minima, when two zones of spots are in evidence, there is only one zone of prominences, while when only one zone of spots exists the prominences are for the most part confined to two zones.

The conclusions arrived at in the present communication may be summarised as follows:—

1. The centres of action of prominence activity undergo an apparently regular variation.

2. The direction of motion of these centres is from low to high latitudes, the reverse of that of spots, which travel from high to low latitudes.

3. At epochs of prominence minima (which are concurrent with sunspot minima) these centres of action are restricted to one zone (about latitude ± 44°) in each hemisphere, while those of the spots occupy two zones in each hemisphere.

4. At nearly all other times these centres are apparent in two zones, while those of the spots occupy only one in each hemisphere.

5. The subsidiary maxima exhibited by the curves representing the percentage frequency of prominence activity for each entire hemisphere, are due to the presence of two well-developed centres of prominence activity in each hemisphere.

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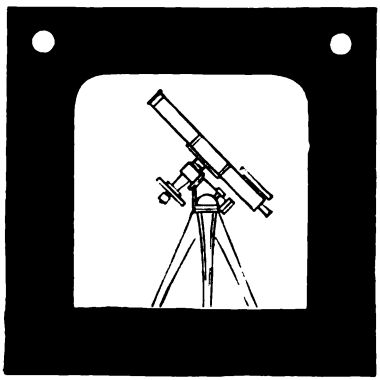

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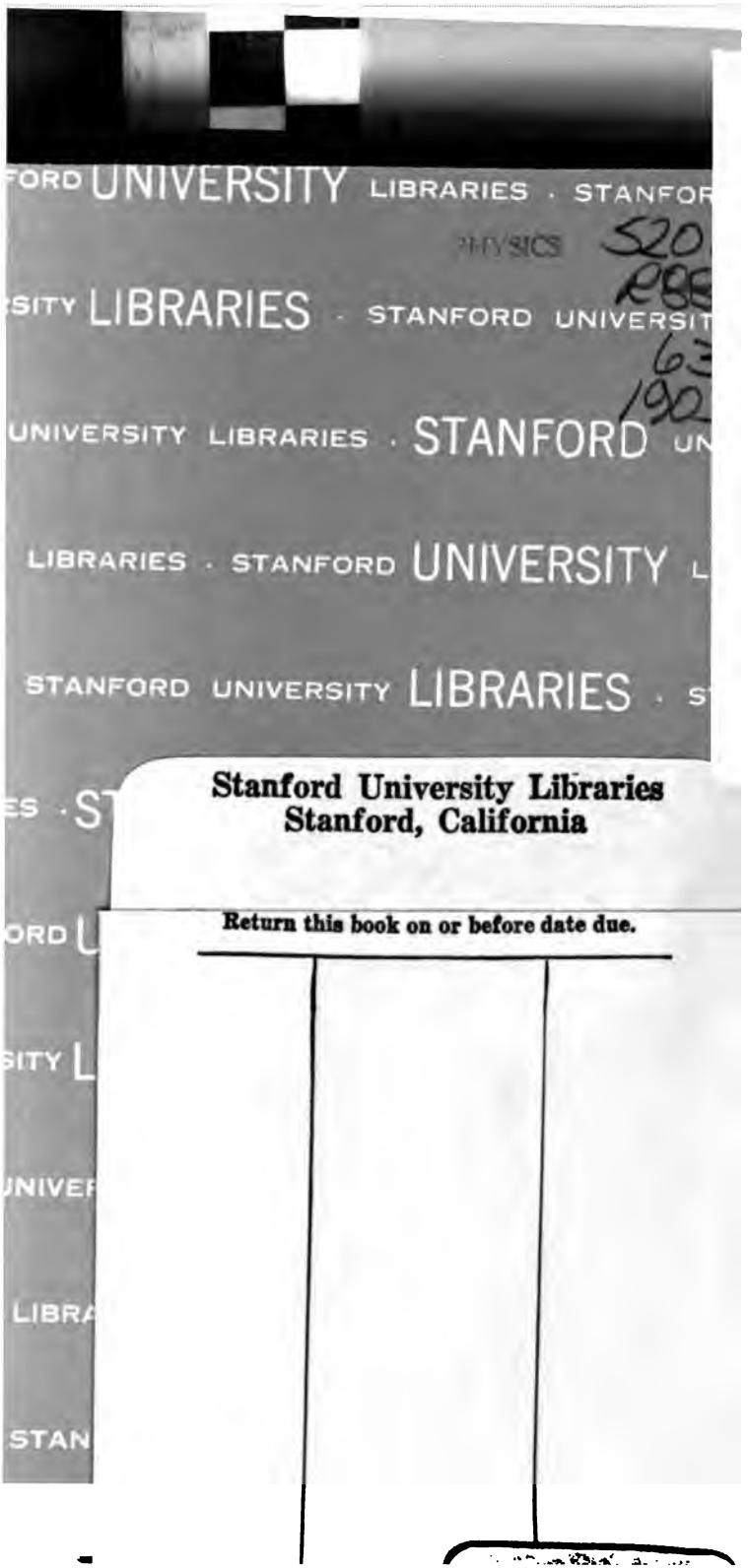
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